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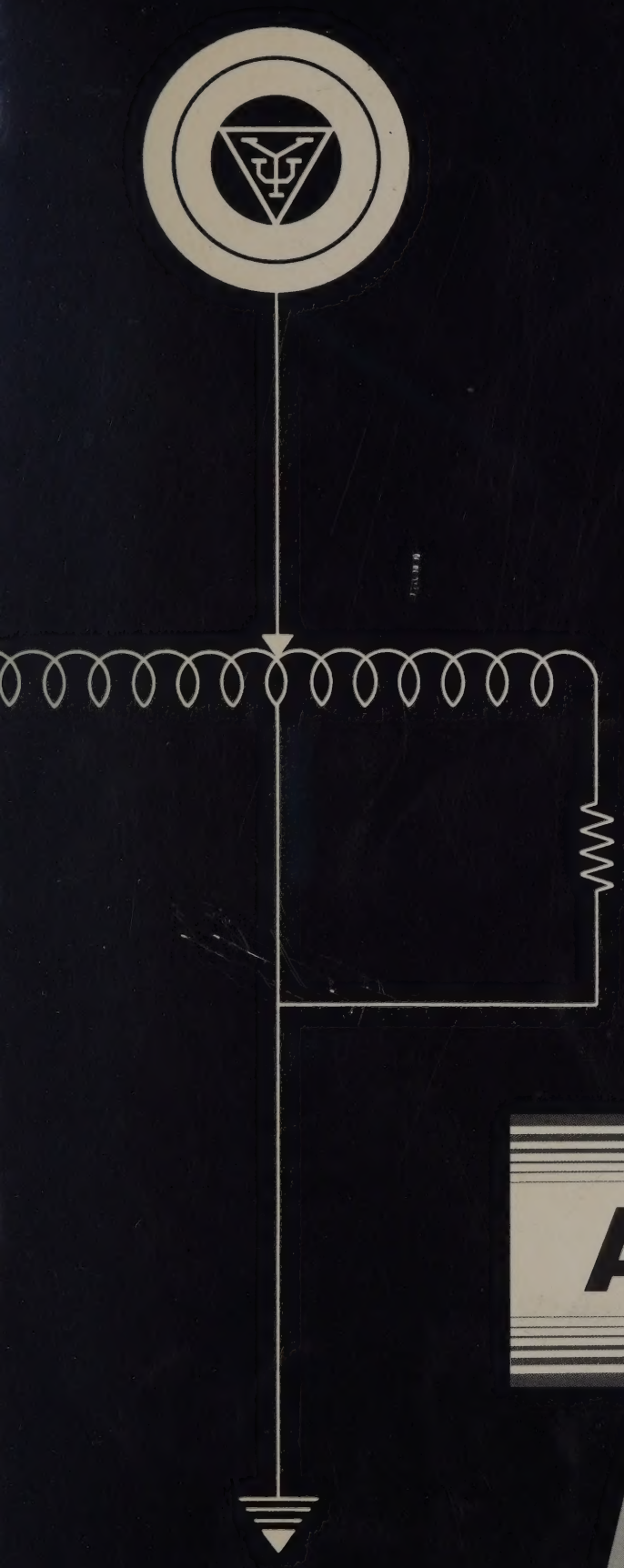

Electronic

INSTRUMENTS

PHASE METERS

DELAY LINES

AD-YU ELECTRONICS, INC.

249-259 TERHUNE AVE.,
PASSAIC, N. J., U.S.A.
PHONE: GR 2-5622
CABLE: ADYU PASSAIC

FORM 76-1

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION
QUALITY ASSURANCE LABORATORIES

LM NO. HRS 5-66-21
DATE 6-1-66

LAB MEMO

TO H. Beadle ADDRESS Department 79
Building 3

SUBJECT Certification of a New Test Instrument

INSTRUMENT NAME:	Microwave Phase and Time Detector
MANUFACTURER:	Ad-Yu Electronics
MODEL NUMBER:	206A
SERIAL NUMBER:	110A
PROPERTY NUMBER:	N820360
JOB ORDER NUMBER:	H66-8938-79

REFERENCES:
(a) Laboratory Report HD-356
(b) Laboratory Report HD-362
(c) Instruction Manual for Microwave Phase and Time Detector, Ad-Yu Electronics Model Number 206A
(d) Lab Memo Number HRS 2-66-18

INTRODUCTION:

The subject instrument was submitted to the Reference Standards Laboratory by Department 79 for certification. The following are some of the important specifications for this instrument:

Range:	0-1000 picoseconds
Accuracy:	Less than ±0.1 degree or ±1%
Frequency Response:	1100 to 6000 mc
Sensitivity:	one picosecond
Ratio of Input Signals:	ten to one
Minimum Signal:	0.5 milliwatts
Maximum Signal:	300 milliwatts

CONCLUSION:

The subject instrument did not meet the requirements given in Reference (c) and is not certified for use. The item will not be added to Reference (a) as an Approved Instrument. The accuracy has been rated at ±(2 percent plus 2 picoseconds).

RECOMMENDATION:

The subject instrument should be submitted to Department 55 every 6 months for calibration or service. This instrument requires Reference Standards for calibration.

Dial resolution = .001 of Full scale or 0.36° @ 1.8 kmc

1% of full scale @ 1.8 kc = 3.6° or ± 2 major dial divisions

Motor Control Switch is interchangeable

DISCUSSION:

Reference (d) rejected the subject equipment because of high input VSWR. The original specification required input VSWR to be less than 1.1. The supplier has since changed his specification to read: input VSWR residual less than 1.2 and defines this value to be different than the VSWR measured by ordinary methods. He further states that the accuracy of phase measurement is practically unaffected by VSWR since the instrument is based on the comparison principle. Reference (c), the manufacturer's instruction manual, however, states under Paragraph 6a "Impedance matching is very important; therefore, in order to achieve consistent and accurate measurements, all connectors and cables should be carefully made and checked to keep the standing wave ratio (VSWR) below 1.05 at all times".

The accuracy is stated to be less than $\pm$0.1 degree or $\pm$1 percent. This appears to be meaningless since no statement is made under what conditions one or the other tolerance applies. At the lower frequencies, 0.1 degrees is 10 times smaller than what can be read on the vernier scale of the dial. Calibration was performed using Precision Reference Standards Air Lines, General Radio Type 900-L. The data indicate that the one percent tolerance could not be met. The instrument accuracy was derated to $\pm$(2 percent + 2 picoseconds). This rating is consistent with dial resolution and accuracy.

The Ratio of Input Signals, as stated on the original specification sheet is 50:1. The instruction manual states this ratio can be no larger than 5:1 and the latest specification sheet states the ratio to be 10:1. It was found that a 10:1 ratio was satisfactory as long as the signal levels were held within the specified limits of 0.5 to 300 milliwatts.

The Power Divider, Ad-Yu Type MC-101 was sub-standard in quality. The connectors had pins that protruded 0.020 inches from nominal. The Specification for these connectors, MIL-C-71, is a plus or minus tolerance of 0.010 inches. The external physical dimensions were not consistent with catalog information and the catalog specification was specified only to 3 gc whereas the Phase Detector operates to 6 gc.

Since the Purchase Order did not contain any detailed specification and the requester stated he can use the equipment with its derated accuracy, the equipment is approved for purchase. The instrument, however, will not be certified or considered satisfactory for addition to Reference (a), the Approved Test Instrument List.

DISCUSSION: (Continued)

Additional data from which this report was written are on file in the Reference Standards Laboratory.

C. L. Habermann

Written by: C. L. Habermann
Sr. Research Engineer

W. T. Boyd

W. T. Boyd, Lead Engineer
Reference Standards
Equipment Test Laboratory
Department 55

CLH:ts

dc: Std. Dist. C
W. Camp - 79
W. Fierstos - 64
R. Feucht - 53
R. Gray - 71
W. Heyer - 71
J. Kaser - 53
W. Marsh - 71
R. Moorhead - 64
R. Rossing - 71

DISCUSSION: (Continued)

Additional data from which this report was written are on file in the Reference Standards Laboratory.

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W. Fleetwood - 64
R. French - 57
E. Grey - 71
W. Hiper - 71
J. Lasar - 57
W. Marsh - 71
R. Moorhead - 64
R. Nuseday - 71

INSTRUCTION MANUAL FOR TYPE 206A

MICROWAVE PHASE AND TIME DETECTOR

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FIGURES:

1. System Schematic Diagram
2. Type 200C Chopper Amplifier
3. Type 200P2 Power Supply
4. Reading 206A Vernier Scale
5. Initial Channel Equalization
6. Measuring an Unknown Delay

XERO COPY XERO COPY XERO COPY

SYSTEM RELATIONSHIPS

The Type 206A Microwave Phase and Time Detector operates upon the comparison principle, utilizing two signal-delay channels feeding into an interchangeable sum/difference vector network, the outputs of which traverse matched detectors into comparison circuits of selectable nulling mode; these relationships are presented in Figure 1, the System Schematic Diagram. The input signal to the E1 channel traverses a precision-calibrated continuously-variable delay line, and then a 3 db attenuator (for isolation of mis-match) to enter the microwave bridge: the SUM/DIFFERENCE network. Similarly, the E2 channel signal traverses an "equalizing" delay line and matching 3 db attenuator, before entering the sum/difference network. The two network outputs (vector sum, and vector difference, of the input signals) are fed through a matched pair of microwave detectors, and then through a pair of high-resolution ATTENUATION controls, into the "NULL FOR" mode-selecting switch, S-1. The function so selected enters the comparison circuitry consisting of: a SENSITIVITY Switch; a sensitive, balanced Chopper Amplifier; and a zero-center microammeter for null indication. Provision for external nulling indication has been made, for extension of instrument utility to include pulsed signals.

CIRCUIT DESCRIPTION

Unlike the Type 205 Series Precision Picosecond Phase Detectors, the Type 206A Microwave Phase and Time Detector has a self-contained Continuously Variable Delay Line, with its residual-delay-equalizing line; also, the "step delays" of the separate Type 20B Unit are not required. This results in simpler cabling and controls, as well as in reduced overall size.

The (interchangeable) sum/difference network is the "Plug-In Unit", three of which are included with each instrument to cover the frequency band; obviously, the proper frequency-range to match the input signals must be utilized. Detectors D1 and D2 are matched crystal units connecting into these "Plug-In Units" in opposed locations -- by two of the four couplings required for those interchangeable units.

The ATTENUATION controls (R1 and R2, for the E1 and E2 channels, respectively) are dual-potentiometer units for increased resolution in the critical channel-balancing procedure. The rectified signals traverse these controls to enter S1, the function- or mode-selecting switch ("NULL FOR") -- and then go to the Balanced Chopper Amplifier through the signal-level-controlling SENSITIVITY Switch, S2.

The circuit schematic of the Balanced Chopper Amplifier is shown in Figure 2. The balanced-input filter greatly reduces the sensitivity to the power-line frequency -- at which the chopper operates -- with 60 cps normally supplied (50 cps being available upon special order.) The single-pole, double-throw chopper switch alternately samples the dc signals of the dual inputs, the square waves being amplified by the four-stage feedback amplifier. Demodulation is accomplished through the synchronized circuit of transistor Q1, yielding a metered output

proportional to the difference between the levels of the input s[illegible]s, and permitting very sensitive equalization of them by nulling of [illegible] meter. The 250K potentiometer (R-32) is the panel-mounted ZERO ADJUST control, for the meter.

The regulated power supplies are shown in Figure 3. The ten volt supply delivers direct current for the heaters of tubes V1 and V2 of the Chopper Amplifier. Terminal #12 is high-voltage a.c. (through 470K ohms) which is cabled to terminal #10 of the Chopper Amplifier -- for use as the 60 cycle (50 cycle, for special orders) synch signal for Q1.

PANEL CONTROLS

"E1 IN" -- Type N female coaxial connector, with 50 ohms characteristic impedance, for introduction of the E1 signal, of the measuring channel (which contains the continuously-variable delay line.)

"E2 IN" -- Type N female 50-ohm coaxial connector, for the E2 channel (Any other type of input connectors for the E1 and E2 channels can be supplied upon request.)

"E1 VARIABLE DELAY" -- the precision-scaled variable-length delay mechanism, with large two-speed control knobs located beneath the panel meter; this scale is calibrated in picoseconds (uu sec.), the vernier reading of this unit. For still higher resolution, a "Super Vernier" is available.

"ATTENUATION" Controls -- the lower pair of the four grouped control knobs, the left (marked " E1 + E2 ") controlling the signal level of the vector-sum, with the right-located knob controlling the vector-difference signal for balancing of the detectors. These are the high-resolution dual-pots, R1 and R2 respectively, each containing a vernier adjustment.

"NULL FOR" Mode Selector -- a four-pole, four-position, switch (S1 in Figure 1) by means of which the operational mode of the meter-nulling procedure is established. (See OPERATING PRINCIPLES AND TECHNIQUES)

"METER SENSITIVITY" -- a two-pole, five-position rotary switch (S2 in Figure 1) located as a Panel Meter control, for controlling the signal level of the input to the Chopper Amplifier. It should be set at "MIN" during cabling or other input-level changes, and at "MAX", or near maximum, during final nulling.

"METER ZERO" -- the 250K (R-32) potentiometer, located near the meter, for control of the operating level of the demodulating transistor circuit; rather frequent adjustment to meter zero is recommended (with "NULL FOR" selector temporarily at "EXT") to compensate for d.c. drift -- although overall accuracy may not be reduced by such drift of the nulling level.

"TO EXTERNAL INDICATOR" -- a three-pin female Amphenol connector (#91PC3F), for delivery of the outputs of the crystal detectors to an oscilloscope or to an external null detector; #1 pin is grounded, #2 pin is the "vector sum" (D1) connection, and #3 pin carries the "vector difference", from D2. This connector is located on the right side-panel, forward and upward (behind the "NULL FOR" selector.)

"POWER" -- toggle switch to control the 60 cycle, 115 volt ±10%, primary power (50 cycles, and/or 230 volts, available upon request); no pilot light is required for the Type 206A, because the scale-illuminator lamp of the Variable Delay serves this function. If this lamp fails to light, check the fuse at the rear of the chassis: AGC, 2 amp.

SUM/DIFFERENCE (PLUG-IN) Network -- located internally -- near the rear of the instrument, behind "E1 IN" on the front panel.

OPERATING PRINCIPLES AND TECHNIQUES

1. System Utilization Fundamentals

The input signals, E1 and E2, are assumed to be relatively clean sine waves; harmonics, noise and standing wave ratios (VSWR) of more than a few percent may cause false nulls or other errors. It is also assumed that these two input signals are within 2 or 3 db of equality -- using external attenuators if necessary. (CAUTION: ALWAYS ACCOUNT FOR THE TIME-DELAYS OF ATTENUATORS, FILTERS, ETC.)

The fundamental linearity and precision of this instrument is enhanced by careful design incorporating highest quality components, and low-loss cables and connectors. Because the time delays are truly additive, the initial "equalization" reading upon the continuously-variable delay becomes the reference time (or phase) from which the time-delays of inserted "unknowns" are differentially measured. This is also the basis of its adaptability to various techniques of precision measurements: substitution methods; cascaded calibrations; transfer comparisons; and interchange checking. With reasonable care, the time-lags of additional cables and/or networks can be determined, and these -- together with attenuation ratios -- can be simply combined for synthesis of reference networks useful for comparison or substitution in differential measurements of high-gain, or high attenuation, systems.

In the practical use of the Type 206A Phase Detector, it may be preferable to measure phase-lead (or else additional-time-to-end-of-period) especially if this value is much less than its lag-equivalent. To accomplish this, simply interchange the input cables: "E1 IN" to "E2 IN", and vice versa.

2. Time-Delay and Phase Relationships

Throughout this manual, procedures for the measurement of time-lags are discussed -- since these are of fundamental importance, and since their relationships to phase-lags are straightforward:

for time-lags less than the period of one electrical cycle (reciprocal of the frequency) the time-lags are proportional to the phase-lag:

$$\theta = 360\ t/T = 360\ t.f \quad \text{(Equ. 1)}$$

where f is the frequency in gigacycles per second or gigahertz (Gc or GHz), T is the period of the wave in nanoseconds (reciprocal of f, in Gc or GHz), t is the time-lag in nanoseconds (ns), and θ is phase-lag in electrical degrees.

In general, phase-detector circuits will produce a null indication at each time-based coincidence of the sine-waves being compared: at 0°, 360°, 720°, etc.; usually the differences in cycle-integers or periods are known or readily determinable. Because the Type 206A instrument indicates TWO nulls per electrical cycle with the SUM/DIFFERENCE method, it is important to be able to determine not only the number of electrical cycles to be added to the measured phase-lag (or number of wave-periods to be added to the measured time-lag) but also whether the number of half-cycles (or half-periods) is an odd or an even integer. Skillful operation of the instrument includes this "sensing" requirement, as discussed under OPERATING INSTRUCTIONS, for each method of use; alternatively, the frequency-change technique, for greater than single-cycle use, can be applied to half-cycle counting -- as shown in the following section, numbered "5".

3. The SUM/DIFFERENCE Nulling Method

For the usual measurement cases, wherein signal frequency is constant, this quadrature (90° or 270°) capability possesses many advantages; foremost among these is the characteristic that the null is independent of the signal amplitudes, within reasonable limits -- and is relatively insensitive to fluctuations in the signal amplitudes.

The vector diagram illustrating the basic principle is shown in the printed bulletin, together with the picturization of the rejection of even harmonics. The necessary quadrature phase relationship of the two input signals is established by the nulling procedure, which establishes the vector rectangle by equalizing the absolute values of the vector sum and of the vector difference, of E1 and E2.

However, for measurements to be made under conditions of frequency instability -- with amplitudes relatively constant -- the DIFFERENCE ("DIFF", or "0°") method should be used. This is because a sharp and stable null cannot be obtained without freq-quency stability, with the SUM/DIFF nulling method. This will be described under OPERATING PROCEDURES.

4. The DIFFERENCE Nulling Method

This mode of operation is particularly recommended whenever instability of the signal frequency exists, because nulling is accomplished by equalizing the time-delays within the two channels -- which delays are unaffected by signal frequencies. (The SUM/DIFF

mode requires a 90°, or 270°, phase-difference is one channel to achieve nulling -- causing sensitivity to frequency changes.) Amplitude stability is the primary requirement for use of the DIFFERENCE nulling method -- since differences in the signal amplitudes can be accomodated by proper use of the METER ZERO and METER SENSITIVITY controls.

Note that the SUM nulling method, though a vector extension of the DIFFERENCE method, is not insensitive to frequency changes -- since a 180° phase-difference must be maintained.

5. Method for Measuring Larger Values of Phase-Lag

The following method for measuring phase angles greater than one basic period of any phase detector (whether 180° or 360°) is due to Dr. Y.P. Yu, President and Chief Engineer of AD-YU Electronics, Inc. It utilizes the equality of total time delay (D), in an "unknown" undergoing measurement, at two frequencies sufficiently close together (f and f'); the most important condition upon the choice of auxiliary measuring frequency (f') is that it does not change the number of basic periods (n). Thus, if an observed value of time-lag (t = t2 - t1) is only a small fraction of 180°, it would be better to choose an auxiliary measuring frequency (f') of slightly higher -- rather than lower -- value, so that the measurement null would not traverse zero into a region of higher apparent time-lags (due to reduction of n by one unit); similarly, if time-lag t approaches the value for the basic period (T = 1/f, or half of this value for 180° intervals) the auxiliary measuring frequency (f') should be somewhat lower than f. In practice, the null can be "tracked" while slowly changing f -- to make sure that a measurement null is not traversed.

For the Type 206A Phase Detector, it is better to let n represent the number of half-periods (time-intervals of 180° each) in order to furnish a test upon "sensing" tests indicative of third- or fourth-quadrant phase lags; for this case, t and t' cannot exceed half-period values (1/2f and 1/2f'):

$$D = t + nT/2 = t' + nT'/2 \qquad \text{(Equ. 2)}$$

where: D is the total delay time and n is the number of half-periods of 180 electrical degrees (both D and n being the same value for both sets of measurements); t = t2 - t1 and t' = t2 - t1' (at frequencies f and f', respectively); T and T' are the periods of the respective waves (and the reciprocals of these frequencies.)

$$D = t + n/2f = t' + n/2f' \qquad \text{(Equ. 3)}$$

$$n(f' - f) = 2ff' (t' - t) \qquad \text{(Equ. 4)}$$

$$n = \frac{2ff'(t' - t)}{f' - f} = \frac{2(t' - t)}{\frac{1}{f} - \frac{1}{f'}} \qquad \text{(Equ. 5)}$$

Note that n (the number of half-periods which must be added to the observed time-lag, t, to obtain total time-delay D) is always positive. Although a negative value of t can, of course, represent a value of phase-lead (of E2 with respect to E1) for phase-angles less than 360°, a negative value of n is indicative of error in the selection of f' -- showing that a phase-null was traversed, with Equ. 2 (and subsequent development) no longer valid. If in doubt, use more than one "auxiliary measuring frequency".

The complete expression for total time-lag is obtained by substituting the first of the two expressions for n (in Equ. 5) into the first half of Equ. 3:

$$D = t + \frac{f'(t' - t)}{f' - f} \qquad \text{(Equ. 6)}$$

Both t and t' must be obtained as the differences between pairs of measured values; the channel "equalization" values (t1 and t1') will not remain the same for the changed frequency value.

The expression for the total value of phase-lag (P), for t less than one-half period, in degrees, becomes:

$$P = 360\ t.f + 180n \qquad \text{(Equ. 7)}$$

6. Utility of the ATTENUATION Controls

Unlike the similar controls of the Type 205B1 Phase Detectors (but exactly like those of the Type 205B-4) the ATTENUATION controls serve solely for sensitive equalization of the pair of crystal detectors, and not for "two-variable nulling" characteristic of the Type 205B-1 instrument. Therefore, especially for use by technicians familiar with that lower-frequency Precision Picosecond Phase Detector, it is very important to note that THESE ATTENUATION CONTROLS MUST NOT BE CHANGED FOLLOWING THE INITIAL "DETECTORS BALANCE" OPERATION.

7. "METER ZERO" and "METER SENSITIVITY"

The zero adjustment of the output meter is actually a sensitive control of the differential operating levels of the direct current outputs of the two crystal detectors; to compensate for d.c. drift (due to temperature or other changes) rather frequent checking of this adjustment -- always with the "NULL FOR" selector in the "EXT" position, without "external" connections. Although it might seem that, for the DIFFERENCE method at least, this "METER ZERO" potentiometer could be utilized for a "position control" to compensate for differences in amplitudes of the input signals (permitting increase of SENSITIVITY during the nulling operation), this procedure is not recommended because the Chopper Amplifier could be saturated thereby, with loss of nulling effectiveness. Because this meter has a full-scale sensitivity of the order of 50 microvolts, ALWAYS KEEP THE SENSITIVITY SELECTOR AT MINIMUM DURING CIRCUIT CHANGES, STAND-BY, WARM-UP, ETC. -- TO PROTECT THE SENSITIVE METER.

The "METER SENSITIVITY" selector actually controls the signal level at the input to the Balanced Chopper Amplifier -- which is the reason why the zeroing adjustment of the meter must not be used for a nulling-position control.

8. False-Null Procedures

For various reasons, regional minima of panel-meter readings can occur -- so it is very important to detect and to correct such false-nulls. The cause may be indicated by the nature of the null itself: a broad, insensitive tuning characteristic may be due to inadequate signal strength, to excessive amounts of noise and/or harmonics, or to the ratio of signal inputs of the channels exceeding 5 or 6. Correction of such symptoms is important whether or not a false-null occurs -- since a smooth and sharp tuning characteristic is indicative of proper utilization of the instrument.

The most useful test for a true null, which should be made prior to acceptance of each measurement, is the changing of the "SENSITIVITY" selector -- counter-clockwise rotation from the "MAX" position to the "MIN", and then back to "MAX", should produce no increase in the meter reading at any step of the switching.

A false-null may show off-scale meter values (either positive or negative) on the first or second step of "SENSITIVITY" reduction. If no open-line exists and no impedance mismatch seems probable (either might be due to faulty hardware), try reducing the signal level, or reduce the ratio between two inputs. If the changing of "SENSITIVITY" produces large shifts in meter reading, the false-null still exists; next try a 3 db (or greater) attenuator in the input line carrying the higher signal level. Do not forget to account for the additional time-delay of the attenuator, or to re-equalize the channels.

PRELIMINARY OPERATING INSTRUCTIONS

1. Meter Protection, and Warm-up

Always set the "NULL FOR" selector to "EXT" before turning the Type 206A on -- and also before every type of circuit change involving cables -- to protect the sensitive meter. Likewise, make it a habit to keep the "SENSITIVITY" selector at or near "MIN"; never leave this on "MAX" after taking readings, even if the instrument be turned off prior to disconnections.

Warm-up of about ten minutes is recommended; this time may be utilized for hook-up with safety because the input to the Chopper Amplifier is grounded with "NULL FOR" at "EXT". Due to the various possibilities for maximum unbalance (including cabling errors) when switching away from "EXT", it is most important to have "MIN" SENSITIVITY at this time.

2. The Plug-in Units

The most important of the cabling changes (which must be made with "EXT" position selected by "NULL FOR") is the choice of the proper one of the three interchangeable SUM/DIFFERENCE Networks, for the signal frequency to be utilized. This

"Plug-In Unit" is located internally, behind "E1 IN" on the front panel, at the back of the instrument; it may be reached only by removal of the cover (including the back) of the cabinet.

Disconnect the pair of crystal detectors, from the cross-shaped SUM/DIFFERENCE Network, and then simultaneously disconnect that Network from the Type CA-H coaxial attenuators -- which are rigidly supported to facilitate these changes. Install the Network of proper frequency range by careful, simultaneous, manual engagement of both coaxial couplings, followed by tightening of the two ring couplings at the same time. Next install the pair of crystal detectors using care to match "E1 MINUS E2" to the similarly-labelled side of the Network, and the vector sum detector to the opposite side.

3. Signal-Level Considerations

A minimum of 50 millivolts per channel is recommended for the input signal level -- for use without an external indicator. If a sensitive external receiver (sensitivity of about one micro-volt) is used for null indication, signals as low as 5 millivolts can be used. Somewhat higher signal levels are recommended, even for use by skilled operators, and with signals of high stability. The maximum recommended signal level is 4.0 volts rms.

The "unknowns" measured for time-delays or phase relationships may consist of amplifiers or signal attenuators -- in which case signal amplitudes must be adjusted in order that the inputs to both channels be between 50 mv. and 4 volts -- and also that the ratio of these channel inputs not exceed about 5 to 1. Delays of attenuators must be measured, and cascaded-delay techniques should be used.

4. "METER ZERO" Adjustment

This first step in instrument calibration is one which should be repeated every half-hour or so during use. The "NULL FOR" selector must be in "EXT" position when this adjustment is made; because the outputs of the crystal detectors are switched off by this selector, it is not necessary to remove the input signals to effect scale-centering by the METER ZERO adjustment. The "SENSITIVITY" selector should be at "MAX" for this adjustment, then returned to "MIN" (or to previous level if not making the Preliminary Set-Up); deviation from zero at any step of the "SENSITIVITY" selector, between "MAX" and "MIN", is indicative of switch-contact trouble.

5. "ATTENUATION" Settings for Balancing Detectors

This operation is required only for use with the SUM/DIFFERENCE method of nulling; for changing to "DIFF" or "SUM" methods, simply leave these controls at their previous "balancing" positions. (For minimum attenuation of the signal of the detector being used for "SUM" or "DIFF" method of nulling, the ATTENUATION control for that detector should be at its maximum counter-clockwise position.)

Balance Procedure

Temporarily terminate "E2 IN" with the 50-ohm coaxial termination supplied with the instrument. Set the vernier (center) knobs of the ATTENUATION controls to near-center locations, and the outer knobs to their minimum (ccw) positions. With SENSITIVITY selector at "MIN", switch "NULL FOR" to "SUM/DIFF"; then apply a signal (of about 100 mv.) to "E1 IN". Using one of the ATTENUATION controls, adjust the meter toward zero; if the unbalance increases, return the chosen control to minimum attenuation (the ccw stop) and adjust the other control to null the meter -- increasing meter SENSITIVITY, in steps, to "MAX". Return METER SENSITIVITY to "MIN" before proceding. NO READJUSTMENT OF THESE ATTENUATION CONTROLS IS NEEDED, FOR MEASUREMENTS AT THE SAME FREQUENCY -- or at nearly-equal frequencies, because this detector-balancing operation is a broad-band one; since it also equalizes the SUM/DIFFERENCE network, it must always be accomplished after changing the Plug-In Units. Whenever in doubt, recheck. (Because these steps require cabling changes, the "NULL FOR" selector must be at "EXT" both before and after balancing.)

6. General Precautions

(a) Impedance matching is very important; therefore, in order to achieve consistent and accurate measurements, all connectors and cables should be carefully made and checked -- to keep the standing wave ratios (VSWR) below 1.05 at all times.

(b) In order to achieve proper nulls, the waveforms of both input signals should be clean. Odd harmonics and uncorrelated noise are not cancelled out in the phase null detector, and result in broadened or faulty null indication.

(c) Frequency stability increases measurement accuracies for any operational mode, being least important for the DIFFERENCE method.

(d) Amplitude stability of the input signals is also generally desirable, being most important for the DIFFERENCE and SUM methods, and least critical for the SUM/DIFFERENCE ($90^{o}/270^{o}$) nulling method.

(e) Do not apply signals possessing high values of d.c. components; failure to observe this may result in damage to the microwave detectors.

(f) Semi-rigid coaxial cables are recommended wherever possible, for maximum stability and repeatability. Movement, and/or vibration, of input cables can cause changes deleterious to precision measurements.

(g) Especially for use with the zero-centered nulling of the SUM/DIFF method, "METER ZERO" should be checked frequently, (with "NULL FOR" at "EXT") to avoid error due to d.c. drift.

(h) Errors due to d.c. drift are greatly reduced by use of identical nulling as discussed on page 11, especially in item (a) thereon.

OPERATING INSTRUCTIONS

1. Initial Channel Equalization

Because this instrument is based upon the comparison principle, initial balancing is required regardless of operational mode; this "channel equalization" must be repeated whenever the signal frequency is changed or whenever any change in cabling (other than insertion of the "unknown" or previously-calibrated components) changes the established "initial condition" -- the measured value of which is the reference time, t1.

After completing the Channel-Balancing procedure, remove the signal input and, as shown in Figure 5, connect equal (or nearly equal) cables "A" and "B" from the AD-YU Type MC-101 Power Divider to "E1 IN" and "E2 IN". Cable B may consist of two portions in series, to facilitate later connection of the "unknown" component into the E2 channel. Connect the signal generator to the Power Divider input, applying 100 millivolts or more, preferably gradually -- after switching "NULL FOR" to the selected nulling method. Now use the control knobs of the Continuously Variable Time Delay to effect a null on the Panel Meter, increasing SENSITIVITY in steps which retain on-scale readings.

For the SUM/DIFFERENCE method, the null will be at the center of the meter scale -- and "MAX" SENSITIVITY may be utilized. For the DIFFERENCE method, the null will be near the center of the meter but not necessarily at the center; unlike the null of the SUM/DIFF method, the meter pointer will approach null from the right (moving ccw) for the DIFFERENCE method -- indicating null by its maximum counter-clockwise position, and then will move to the right again if the null has been traversed. When the null reading has been obtained, the reading of the Continuously Variable Delay scale (in picoseconds) should be recorded as t1, the reference time from which unknown delays can be measured -- using unchanged cabling and signal frequency. Return SENSITIVITY to "MIN", and switch "NULL FOR" to "EXT" before opening the cables. THE SUM/DIFF NULLING DEFLECTS METER CW AS E1 DELAY INCREASES.

2. Measuring an Unknown Delay, or Phase, by the SUM/DIFF Method

Using the same cables used for Channel Equalization, (with SENSITIVITY at "MIN") insert the "unknown" to be measured into the E2 channel, by means of cable (or cable-pair) "B" -- as shown in Figure 6. Obtain a new null using the same zero-center nulling method used for "Initial Channel Equalization", "NULL FOR" being at "SUM/DIFF" as before. Record the new setting of the Variable Delay as t2 (also in picoseconds); this value minus the reference-time (t1) is the time-delay of the "unknown" -- which was inserted into the E2 Channel following Equalization.

For time-delays less than one-half period (and phase lags less than a half-cycle) of the signal frequency, f, no especial precaution is necessary in applying the equation given upon the instrument panel PROVIDED THAT "F" IS IN TERAHERTZ UNITS (teracycles per second, or mega-mega cps):

$$\theta = \text{Phase Lag, in degrees} = (t2 - t1) \times 360 \times f \qquad \text{(Equ. 8)}$$

Note that, for this simple case (t2 - t1) is the time-lag "t" of Equation 1, except numerically in picoseconds (ps, or uus) instead of nanoseconds.

The test for whether or not the measured time-delay "t" (or "θ", the phase-lag) is in the first (or other odd-numbered) half-period, or half-cycle, lies in matching the direction-of-approach-to-null by the pointer of the Panel Meter to the direction of movement of the E1 Variable Delay. If this Continuously Variable Delay is being increased in indicated-time (indicator moving to the right) as the null is approached, the meter pointer will move through the zero-null from the left, toward the right, for a first or second quadrant phase lag (first, or other odd-integer, half-period of time-delay.) Conversely, if the meter-pointer approaches the center-null from the right (moving to the left) as the Variable Delay of the E1 channel is gradually increased, "t" and "θ" will be in the second (or other even-numbered) half-period or half-cycle -- indicating that one of three alternatives must be accomplished:

important, Record.

(a) the Continuously Variable Delay must be increased until another null (identical in "sense" to that used for Channel Equalization, the measurement of reference-time t1) reversing the meter nulling direction, is obtained THIS METHOD BEING RECOMMENDED FOR MAXIMUM ACCURACY -- AND FOR DIRECT READING OF "t2", yielding a full-cycle value for "t" and an always-even-integer value of "n" for Equation 7 (page 6);

(b) if the reversed meter-nulling-direction must be accepted (due to the Variable Delay scale-position and/or lower-frequency use), then a half-period, "T/2", must be added to the indicated time-delay, t2, for correct "full-period value" -- "n" being an odd-integer in Equation 7, on page 6; or

(c) alternatively, "P" and "t" may be considered to be in the first half-cycle of phase-lead, or to be a measure of time-to-end-of-period, respectively -- if "t" is made negative by subtracting a half-period "T/2" from the measured Time-lag, which must be accomplished for this alternative; note that this indicates that a "proper-direction" null would be achievable diminishing the "E1 Variable Delay" (below "t1") to t2 - T/2.

Interrelating the SUM/DIFFERENCE nulling mode with the other nulling methods: (1) the DIFFERENCE null (if determined by the extreme-left swing of the Panel Meter) establishes the "zero-degree null" for this instrument; (2) the SUM method (with reversed nulling-direction) establishes "180° nulling"; (3) the "matched direction" zero-center nulling with "NULL FOR" at SUM/DIFF establishes the 90° nulling mode; (4) the "reversed-pointer-direction" zero-center nulling with "NULL FOR" at SUM/DIFF establishes the 270° nulling mode; and (5) care in using a nulling-direction, and also nulling-mode, identical for both "t1" and "t2" can make the use of half-period, or half-cycle, values of "t" and "θ" unnecessary (with n always an even number for Equations 2, 5 and 7.) CAUTION: The

"Method for Measuring Larger Values of Phase Lag", given on pages 5 and 6 (though applicable to either 180° or 360° basic periods) is specifically fitted to half-periods, and half-cycles, by Equations 2 through 7; therefore the condition stated immediately preceding Equation 2 must apply for the use of any of them: t and t' cannot exceed half-period values. (If they do, through use of "a" or "b" above, the equations still apply for "n" in half-periods or half-cycles, without retaining the possibility for "n" being an odd integer.)

3. Measuring an Unknown Delay, or Phase; DIFFERENCE Method

The above-described SUM/DIFF Method is the preferred operational mode for this instrument, if the frequency of the input signal, or signals, is stable (amplitude variations being far less important.) If the signal inputs to E1 and E2 channels are not stable as to frequency, but are of relatively unchanging amplitudes, the DIFFERENCE method should be used, for nulling without phase-shift requirements (which would render the null characteristic frequency-sensitive.) Since only one of the microwave detectors is used in this operational mode, the Channel Balancing Procedure (item #5 of the PRELIMINARY OPERATING PROCEDURES) may be omitted if SUM/DIFF will not be used at all.

Following completion of the Initial Channel Equalization (with "NULL FOR" at "DIFF", and the meter pointer swinging from the right to a farthest-to-left nulling), record t1 and then switch SENSITIVITY to "MIN" with signal cut off temporarily, during insertion of the "unknown" into the E2 channel -- using cable (or cable-pair) "B" as shown in Figure 6. Increase both "E1 VARIABLE DELAY" and "SENSITIVITY" until a new null is obtained -- by the same DIFFERENCE method, including direction of nulling, used for Equalization. Record the new setting of the Continuously Variable Delay as t2. Compute "t" and "θ" as described for the SUM/DIFFERENCE method.

4. Using the SUM Method, for Measuring Delay or Phase

Essentially, the SUM and DIFFERENCE methods are identical except as to their 180° phase relationship; therefore, subject to the following operational considerations, the use of these methods involves no difference in procedure:

(a) Using "NULL FOR" in the "SUM" position (needed for both Equalization and Measurement) the instrument null will be obtained at the maximum clockwise position of the Panel Meter; in the unbalanced condition, the meter pointer will be to the left. All indications on that meter are opposite in sense to those of the DIFFERENCE method.

(b) Because the E1 + E2 crystal detector (instead of the E1 - E2 detector) is used for the SUM method, the SUM method allows comparison of these detectors -- for maintenance checking.

(c) The SUM method requires amplitude stability of the signal inputs, for the same reason as that for the DIFFERENCE method; however, unlike the "0°" nulling of the latter method, the "SUM" method also requires frequency stability for clean and sharp nulling.

5. Measuring Delay, or Phase, Between Similar Signals

The Channel Balancing and Equalization procedures must be performed utilizing the reference signal (or, if the signal level is adequate, the "unknown signal" of Channel 2) as the input to the Type MC-101 Power Divider during Equalization; the balancing of the detectors can also be accomplished using a signal to "E2 IN" and a 50-ohm coaxial termination upon "E1 IN".

Following Equalization,(using the selected nulling method) with SENSITIVITY at "MIN" and "NULL FOR" at "EXT" (if the signals cannot conveniently be switch off), remove the Power Divider and then apply the unknown signal to "E2 IN" and the reference signal to "E1 IN". Using the same method as for Equalization, determine t2 -- and then "t" and "θ", as described before.

Check for false-null, by change of the SENSITIVITY selector -- as described on page 7. This is always recommended, but especially for use with more than one input signal.

6. Differential Measurements, of Delay or Phase

In measuring differences, in time-lag or in phase angle, between a Standard or "known" network and an "unknown" network of generally similar nature, differential delay is directly determinable, as follows:

Following channel equalization (and switching "SENSITIVITY" to "MIN") open both channels at the Power Divider -- inserting the "Standard" into the E1 channel and the "unknown" into the E2 channel. Using the selected nulling method, determine "t2" with "E1 Variable Delay". If this time-delay reads a larger value than for Equalization, the positive time-difference "t" represents the amount that the time-lag of the "unknown" exceeds that of the Standard. If, however t2 - t1 has a negative value, this indicates that the phase of the "unknown" leads that of the standard (unless this time-difference exceeds one-half period which means that the "E1 Variable Delay" should have been increased to obtain the nearest null.)

If the time-lag of the "unknown" is less than that of the "Standard", the positions of these may be reversed -- the Standard being inserted into the E2 channel (cables "A" and "B" must not also be interchanged, unless precision-matched) if more convenient to treat phase-lead in this manner.

ADDITIONAL OPERATING TECHNIQUES

1. Measuring Delays Involving Considerable Attenuation

As discussed previously (see Signal Level Considerations on page 8) the signal levels of the inputs to the Type 206A may not differ by more than 14 db, or about five-to-one ratio. Since the

attenuation of an "unknown" network may be much greater than 14 db, and since the same input signal (to the MC-101 Power Divider) should be utilized for Channel Equalization, it is obviously necessary to utilize a coaxial attenuator within the E1 channel -- to make the voltage inputs within range. DO NOT FORGET TO INCLUDE THE TIME DELAY OF THE ADDED ATTENUATORS, which should be subtracted from t1 (even if t1 becomes negative), since added to the measuring channel, E1, following use of the Type MC-101 Power Divider.

All of the AD-YU Type CA attenuators have delay times of about 130 picoseconds. The actual values of delay times may be measured with the Type 206A -- preferably at frequencies near those required for high-precision measurements. By cascading already-measured attenuators -- using them in increasing the total attenuation in the E1 channel input, for successive comparisons of attenuators or other "unknowns" having not more than 14 db greater attenuation -- a set of precision-calibrated (for time-delay values) AD-YU Type CA -- NFNM attenuators is readily achievable. Utilizing one or more of these in the measuring channel, time-delays of networks possessing up to 60 db, or more, of attenuation may be accurately measured -- using a suitably high signal-level at the MC-101 Power Divider.

2. Handling Signals Possessing Large Amplitude Differences

The basic techniques for measuring time-lag, or phase, between similar signals need not be changed if the input signals differ by more than 14 db; it is simply necessary to introduce sufficient attenuation into the channel carrying the greater signal -- at the channel input. DO NOT FORGET TO SUBTRACT THE TIME-DELAY SO ADDED FROM THE MEASURED DELAY. Note the discussion of attenuator calibrations (for time-delay values) in the preceding section.

3. Measuring Delays Involving High-Gain Amplifiers

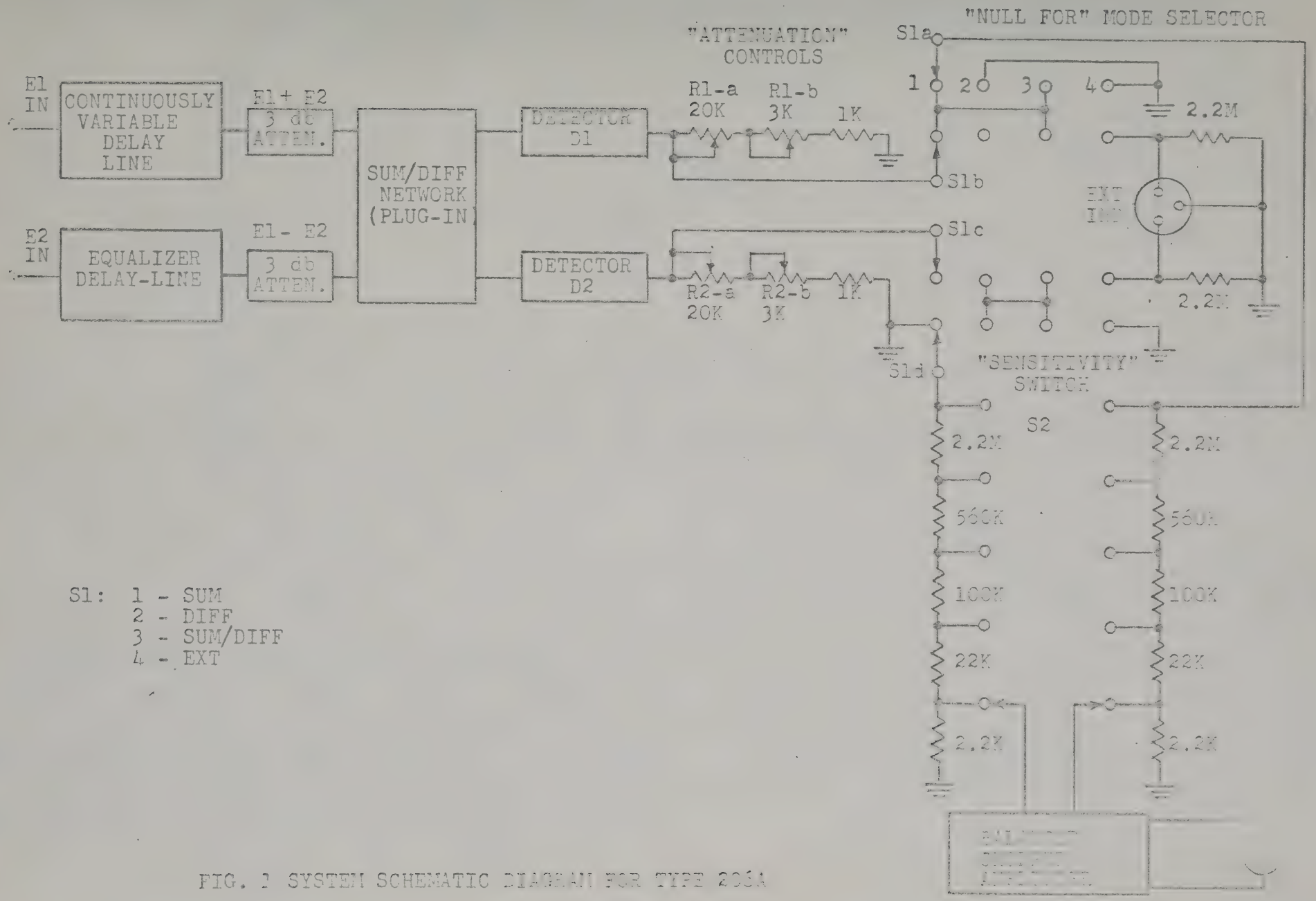
The discussion of the preceding two sections (1 and 2, above) applies to this problem, but in this case the "unknown network" to be measured for time-delay, or phase, must include suitable attenuators at the amplifier output. In addition, it may be necessary to add an attenuator at the amplifier input -- if a 50 millivolt input (from the MC-101 Power Divider) might saturate the amplifier. BE SURE TO SUBTRACT THE ADDED DELAY-TIMES FROM THE MEASURED DELAY, of the amplifier plus associated attenuators.

4. Using External Null Indication

If one or both of the input signals to the Type 206A Unit are below about 50 millivolts, a sensitive external receiver may be utilized. This receiver should perform the function of a differential microvoltmeter, equally amplifying the two d.c. inputs and yielding a null-indicating output.

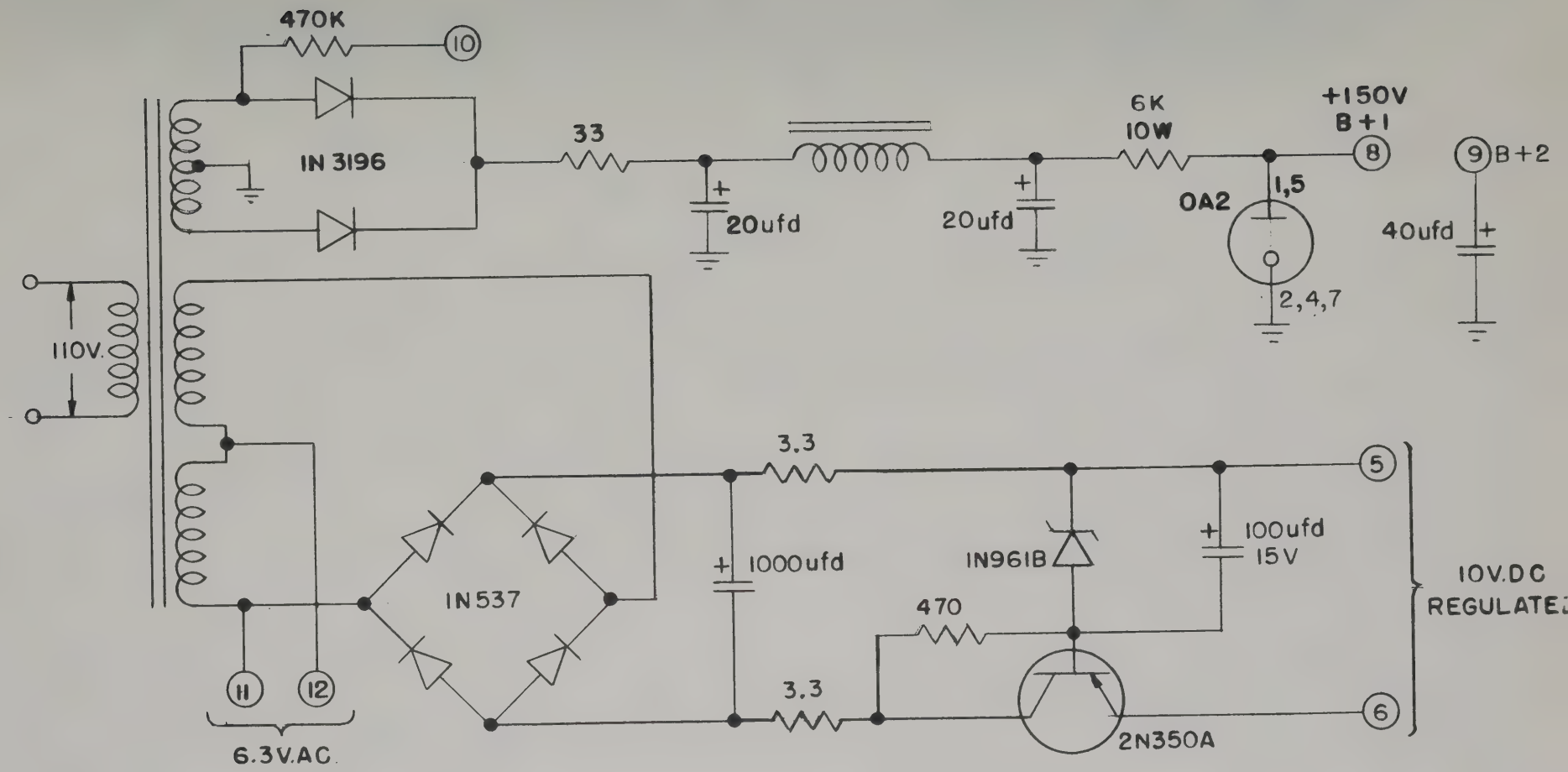
5. Measuring Delays, or Phase, Between Pulsed Signals

If pulsed signals are to be utilized with the Type 206A instrument, "NULL FOR" should be at "EXT" and a high grade oscilloscope, with balanced differential inputs, should be utilized to indicate time-coincidence of the d.c. pulses from the crystal detectors, as "E1 Variable Delay" is nulled.

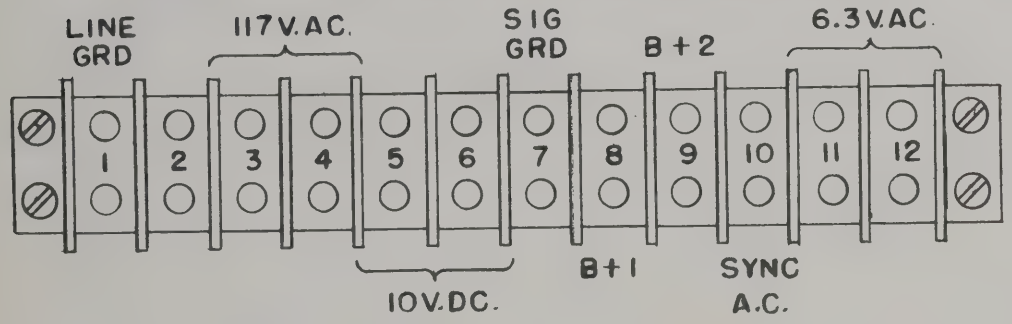


S1: 1 - SUM
2 - DIFF
3 - SUM/DIFF
4 - EXT

FIG. 1 SYSTEM SCHEMATIC DIAGRAM FOR TYPE 206A



TERMINAL STRIP - CONNECTIONS ON POWER SUPPLY.

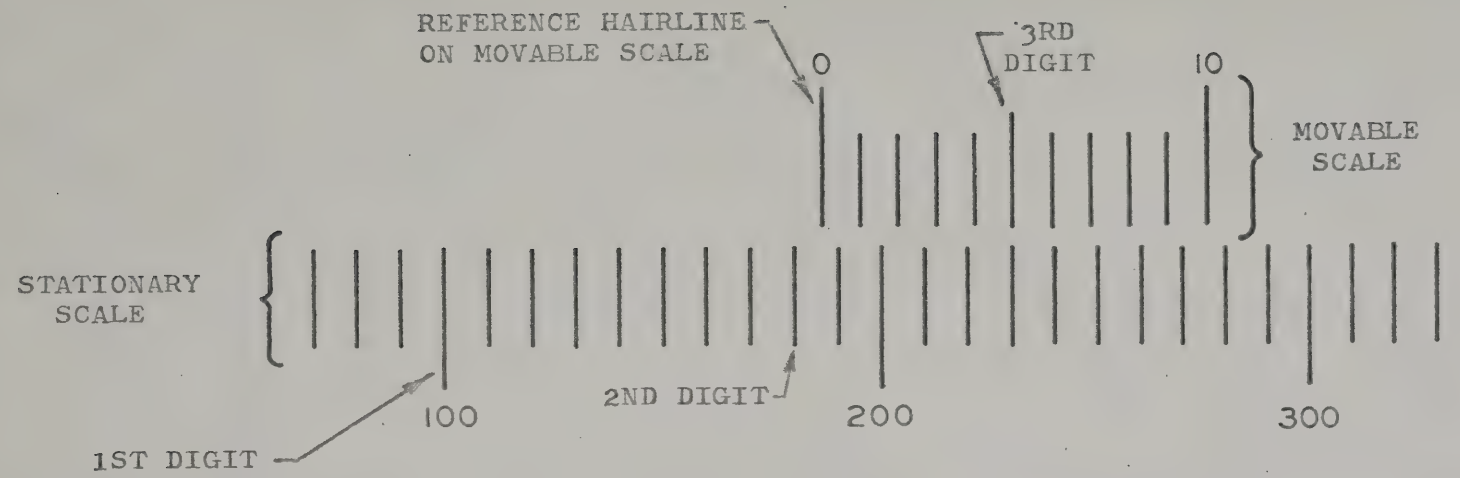


POWER SUPPLY

TYPE 200 P2, FIG.

AD-YU ELECTRONICS, INC.
PASSAIC, N.J.

6.25.64.
10.25.63.



COMPLETE DIAL READING = 185

Detailed Reading Instructions:

1. First digit is first major division on stationary scale to left of reference hairline. In this example, first digit = 100.
2. Second digit is first minor division on stationary scale to left of reference hairline. In this example, second digit = 8.
3. Last digit is that line on movable scale which coincides with a line on the stationary scale. In this example, the third digit = 5.0.

Fig. 4 READING 206 VERNIER SCALE

10.23.63

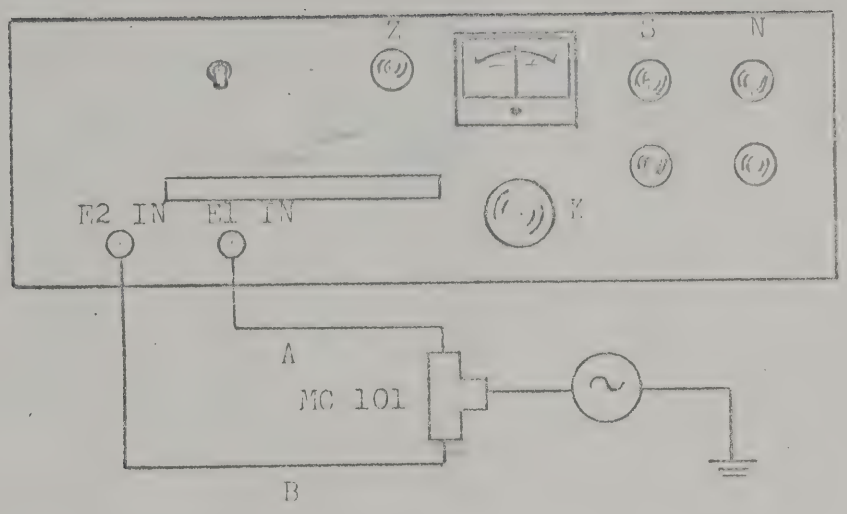


Fig. 5 TYPE 206A INITIAL CHANNEL EQUALIZATION.

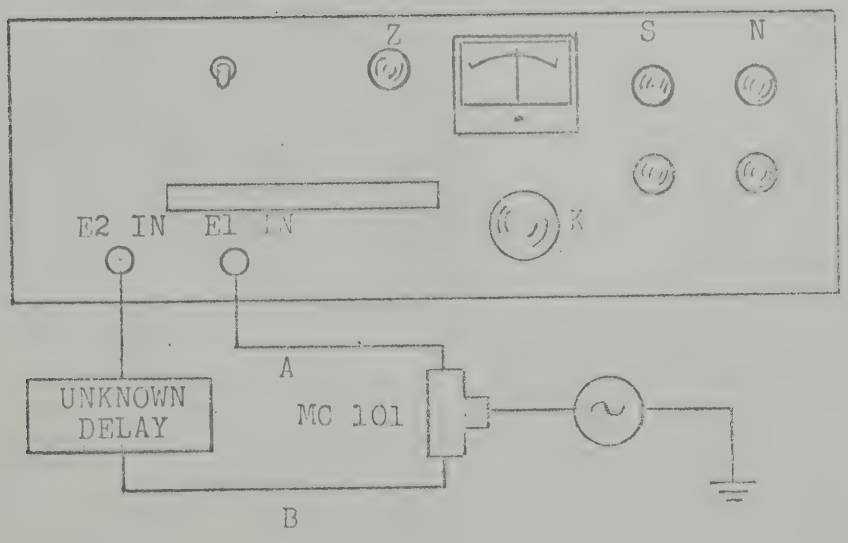
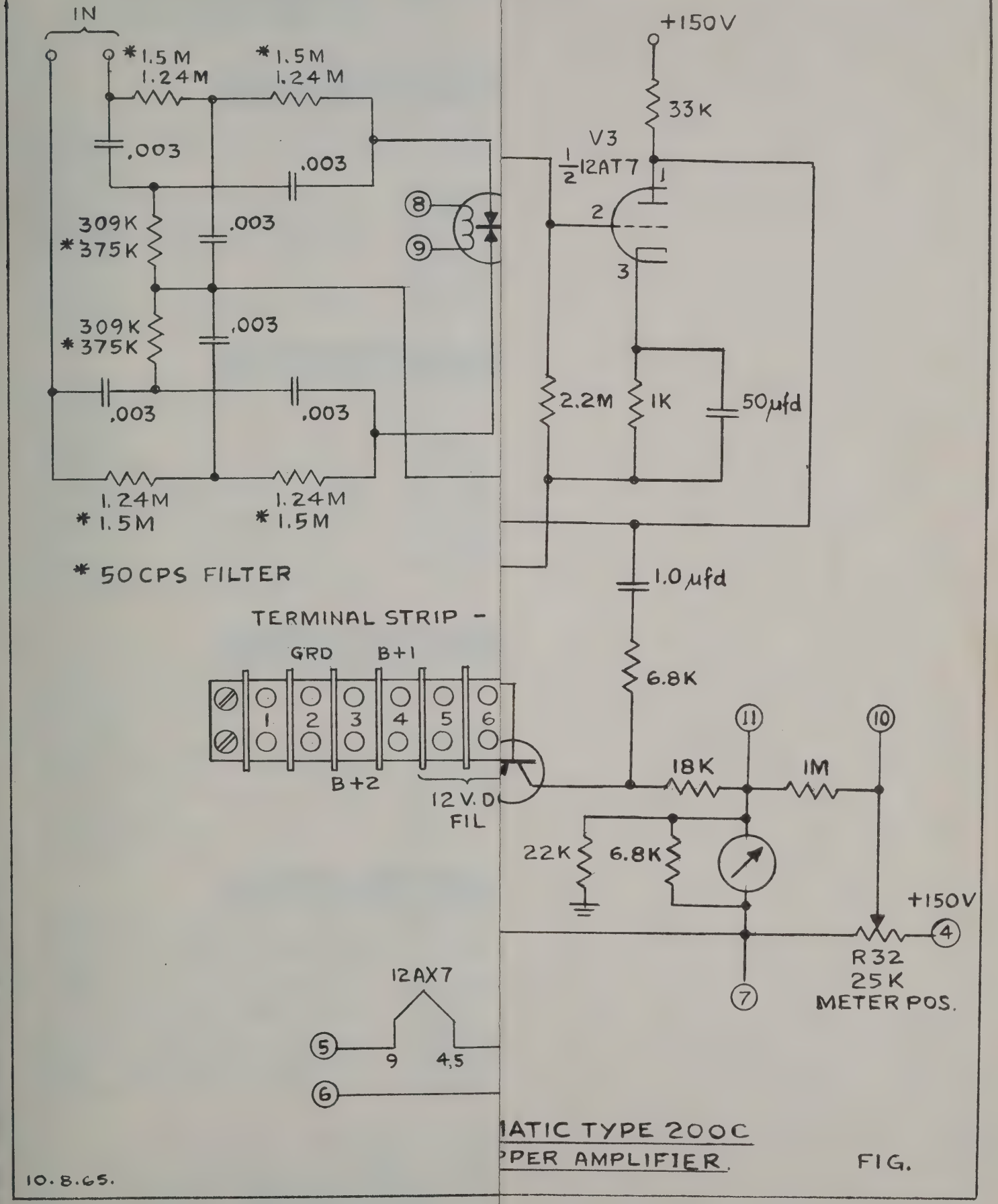


Fig. 6 TYPE 206A, MEASURING AN UNKNOWN DELAY.



IATIC TYPE 200C

PPER AMPLIFIER.

FIG.

10.8.65.

IN

*1.5M
1.24M

*1.5M
1.24M

.003

.003

309K
*375K

.003

309K
*375K

.003

.003

.003

1.24M
*1.5M

1.24M
*1.5M

* 50 CPS FILTER

8
9

.005

220

100 pf

3

+150V

4

33K

1M

1M

V1
12AX7

1

.005

2

6

7

3

8

.02

560K

5.1M

1K

2.2M

47K
1W

+ 4.7µfd

6.8K

+ 50µfd

.005

2.2M

+150V

470K

V2
6AU6

5

1

6

2

.005

.1

1M

+150V

2.2K

220K

+150V

33K

V3
½12AT7

1

2

3

2.2M

1K

50µfd

1.0µfd

6.8K

15K

60~SYNC
IN

12

33K

.02

470

Q1
2N34

11

18K

10

1M

22K

6.8K

+150V

4

R32
25K
METER POS.

7

TERMINAL STRIP - EXTERNAL CONN.

GRD B+1 AC SYNC

1 2 3 4 5 6 7 8 9 10 11 12

B+2

12 V. DC FIL

AC FIL.

12AX7 6AU6

5

9 4,5 3 4

6

12AT7

8

CHOPPER HEATER

9

SCHEMATIC TYPE 200C
CHOPPER AMPLIFIER

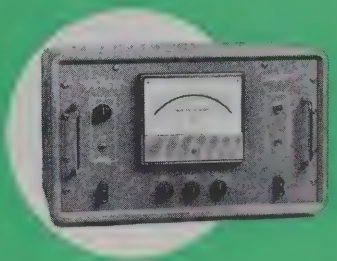
FIG.

10.8.65.

PRECISION PHASE METERS

0.0001 cps to 18,000 mc. Direct reading in degrees or in micro-seconds. Accuracy ±0.05° or ±1%.

PRECISION PHASE METERS TYPE 405 - 405H - 405L



FEATURES • Direct reading in degrees . . . Measures a small fraction of 1° . . . 0.1 volt sensitivity . . . ¼° relative accuracy . . . 1 cps to 500 kc . . . Meter reading independent of input signal amplitudes . . . Equal accuracy for symmetrical waveforms of any shape . . . No adjustment before obtaining reading . . . Useful for automatic plotting of phase response curves . . . Excellent general purpose laboratory phase meter.

Specifications

FREQUENCY RESPONSE: Type 405—8 cps to 100 kc; Type 405H—8 cps to 500 kc; Type 405L—1 cps to 100 kc.

PHASE RANGE: Direct reading in degrees with 8 ranges: 0-12° (0-120° for 405H), 0-36°, 0-90°, 0-180°; panel switch provided for 180° phase shift in order to convert these to 180-192° (180-300° for 405H), 180-216°, 180-270°, 180-360°.

ACCURACY: ¼° relative, ±1° or ±2% of full scale absolute.

INPUT VOLTAGE: Type 405 and 405L—0.3 volt to 90 volts rms; Type 405H—2 volts to 50 volts rms.

INPUT SIGNAL RATIO: Any value between 1 to 100 for 405 and 405L; 1 to 20 for 405H.

CHARACTERISTICS OF OUTPUT SIGNALS: The analog output is zero for 0°, increases linearly to —14 volts for 180° in Type 405 and 405L, to —4 volts for Type 405H, decreases again to zero for 360°.

INPUT IMPEDANCE: Type 405 and 405H—3 megohms shunted by 20 uuf on both input channels; Type 405L—6.8 megohms shunted by 20 uuf.

PRICE: Type 405—$668.00; Type 405H—$725.00; Type 405L—$735.00.

VECTORLYZER TYPE 202 - 202A

FEATURES • Accuracy ±0.02° or ±2% . . . 0.01° deviations can be read . . . Full scale sensitivity 1° or 0.01 volt rms below 100 kc . . . Specially designed for accurate measurement of small phase angle in the vicinity of 0°, 90°, 180° and 270° from 20 cps to 40 kc . . . Lead and log identification provided.

Specifications

BELOW 100 KC:

PHASE ANGLE RANGE: 0-1, 0-2, 0-4, 0-10, 0-20 and 0-180 degrees. A panel switch is provided for 180° phase shift for additional 6 ranges. Expanded scale available on request for ranges of 89-90 (90-91), 88-90 (90-92), 86-90 (90-94), and 80-90 (90-180).

ACCURACY: ±2% of full scale for voltage measurement; ±0.02° or 2% (whichever is larger) for phase measurement.

INPUT IMPEDANCE: 16 uuf shunted with 1 megohm.

VOLTAGE RANGE: 0.01, 0.03, 0.1, 0.3, and 1 volt full scale; plug-in probe having 40 db attenuation gives additional 5 ranges up to 100V full scale.

MINIMUM VOLTAGE FOR PHASE MEASUREMENT: Full scale of 1° requires 0.4V, 2°—0.2V, 4°—0.1V, 10°—0.04V, 20°—0.02V, 180°—0.005V.

ABOVE 100 KC: (Type 202 only).

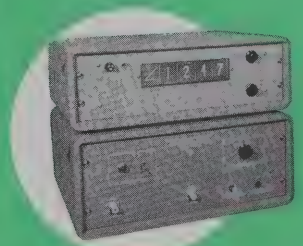
INPUT IMPEDANCE: Coaxial arrangement with BNC connectors for 50-ohm impedance. Jack input probe with 100 K input impedance available on request.

ACCURACY: ±3% below 100 mc, increases slowly up to 5% at 500 mc for both voltage and phase measurements.

VOLTAGE RANGE: 0.4, 2 and 4 volts full scale rms.

PRICE: Type 202—$698.00; Type 202A—$658.00.

DIGITAL PHASE METER TYPE 524A



FEATURES • Phase angle in degrees directly represented in four digits . . . Phase reading independent of the ratio of signal amplitudes . . . Excellent for precision phase measurement . . . No amplitude adjustment, no frequency adjustment for either signal . . . 0.1° resolution . . . Digital or analog output for programmable systems . . . Extremely accurate general-purpose phase meter.

Specifications

FREQUENCY RESPONSE: 20 cps to 500 kc.

ACCURACY: The relative accuracy is ±0.1°, and the absolute accuracy is ±0.3° up to 40 kc, slightly higher above 40 kc.

PHASE RANGE: 0 to 360.0°, displayed in four digits without range switching.

PHASE INDICATION: Digital readout with numerals having 1" height, in four digits.

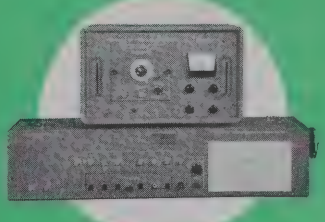
INPUT VOLTAGE: 0.3 volt up to 50 volts rms.

INPUT IMPEDANCE: 3 megohms shunted by 30 uuf on both channels.

CHARACTERISTICS OF OUTPUT SIGNALS: Two forms of output signals available: (1) Analog output for recorder is 0 for 0° increases linearly to minus 3.6 volts for 360°, 1 mv increase for every 0.1° increase. (2) Digital output from digital voltmeter.

PRICE: $2165.00 complete, $965.00 without Digital Voltmeter.

MILLIMICROSECOND PHASE DETECTORS TYPE 205B1-B2-B3



FEATURES • Frequency range 15 mc to over 1700 mc . . . Accuracy ±1% or ±0.05° (whichever is larger) . . . Resolution time actually infinitesimal . . . Single-ended output available for using receiver as external detector for signal level down to 1 mv . . . Automatic plotting of phase curve with plug-in G, H or K . . . Excellent for phase and time measurement of IF amplifiers, filters, transmission networks, klystron, traveling wave tubes, etc.

Specifications

READABILITY: Type 205B1, 205B3—10 uus per division on main scale, 1 uus per division on vernier, 0.01 uus per division with super-vernier; Type 205B2—5 uus per division on main scale, 0.5 uus per division on vernier, 0.005 uus per division on super-vernier.

TIME DELAY: Type 205B1, 205B3—Continuously adjustable from 0 to 2.9 mus (1.4 mus for 205B2), variable in steps of 2.5 mus up to 45 mus (46.25 mus for 205B2).

CHARACTERISTIC IMPEDANCE: 50 ohms nominal for both input and output.

PHASE RANGE: The maximum phase angle is equal to total time delay in us x frequency in mc x 360 in degrees.

FREQUENCY RANGE: Type 205B1—15 mc to 400 mc; Type 205B2 and 205B3—100 mc to 1700 mc.

MINIMUM INPUT SIGNAL: Approximately 0.1v with panel indicator or oscilloscope, 1 mv with external receiver as null indicator for all types.

PRICE: Type 205B1—$2180.00; Type 205B2—$2625.00; Type 205B3—$1615.00.

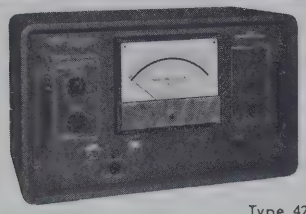
AD-YU ELECTRONICS, INC.

249 Terhune Avenue
Passaic, N. J.

PHONE: GRegory 2-5622
CABLE ADDRESS: AD-YU PASSAIC

NEW PASSAIC LABORATORY

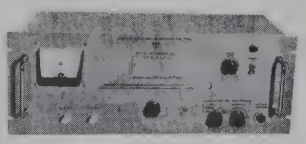
VIDEO AND RF PHASE METER



Type 422

Direct reading of phase angle in degrees without phase adjustment from 50 cps to 10 mc; without amplitude adjustment from 0.5v to 20v. Capable of plotting phase characteristic curve. Frequency range 50 cps to 10 mc. Phase range 0 to +180° or 0 to —180° on mirror scale, 6.5" scale length. Relative accuracy 0.25° plus 0.25° per mc; absolute accuracy ±1° or 2% plus 0.5% per mc. Input impedance 1 megohm shunted by 30 uuf in each channel. Price: $870.00.

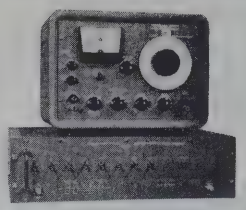
MICROWAVE PHASE & TIME DETECTOR



Type 206

Phase and time measurement from 1100 mc to 18 kmc. Accuracy better than 0.1° or 1% over entire range 0 to 360°. Suitable for pulsed sine wave with no limitation on duty cycle. Accuracy not affected by amplitude fluctuation of both input signals. Infinite resolution. Capable of plotting phase curve. No errors due to meter movement and tolerance of circuit elements. Minimum input signal 5 mv to 300 mv. Frequency range 300 mc to 4000 mc for Type 206A, 3.95 kmc to 18 kmc for Type 206B. Price: $2386.00 and up.

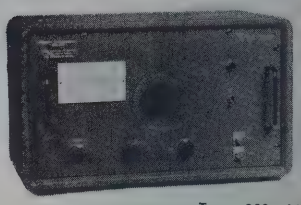
VIDEO & RF PRECISION PHASE DETECTORS



Type 205A1-A2

Measure phase angle down to 0.02°. Excellent for phase and time measurement of filters, amplifiers, etc. at video frequency. Extremely suitable for measuring small phase angles. Frequency range 100 kc to 15 mc. Accuracy ±0.05° or ±1%. Input impedance 3 uuf with low capacity probes; 12 uuf shunted with 1 megohm direct. Input signal 0.1v to 10v. Price: $730.00 and up.

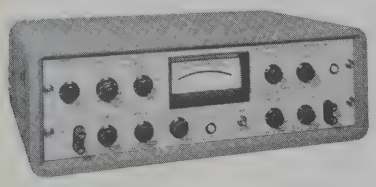
PRECISION PHASE SHIFTER-GENERATOR



Type 208 - 208A

Direct reading in degrees at any one frequency from 50 cps to 5000 cps. Suitable for checking phase measuring devices and servo nulling. Type 208A has built-in tuning fork oscillator. Direct reading in degrees on 3 dials: 0-270° in 90° steps, 0-90° in 2° steps, 0-2½° continuously variable. Accuracy 0.1° relative, 0.15° absolute. Continuous phase adjustment from 0 to 360°. Repeatability better than 0.05°. Price: $495.00 and up.

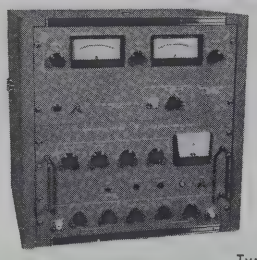
WIDE-BAND PHASE VECTOR VOLTMETER



Type 248

Direct reading of total, fundamental, in-phase, quadrature components and phase angle in degrees on panel meter from 40 cps to 20 kc. Accuracy ±0.25° or ±1%. Read a small fraction of 1° deviation from 0°, 90°, 180° or 270°. Sensitivity 300 uv full scale. Voltage measurement 0.001 to 300v in eleven ranges. Accuracy ±2% of full scale. Continuously adjustable filter available from 50 cps to 20 kc. Price: $725.00 (filter $278.00).

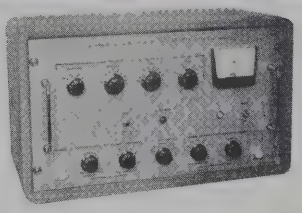
TRANSFER FUNCTION ANALYZER



Type 308

Direct and simultaneous reading of both in-phase and quadrature components without adjustment or computation. Automatic and continuous plotting of transfer function when used in conjunction with an X-Y recorder. Frequency range 0.1 cps to 20 kc. Accuracy ±2% of full scale. Output signal for recorder 1v for full scale sensitivity on any range. Price: $1785.00.

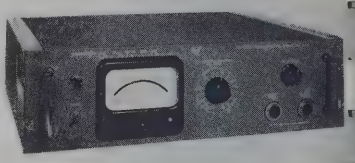
TWO-PHASE DECADE GENERATOR



Type 308G

Provides two simultaneous outputs, 90° phase difference from 0.1 cps to 1000 cps. Essentially constant amplitude throughout entire frequency range. Frequency stability 0.2%, accuracy ±2%, frequency control 4 decades, distortion less than 1.5%. Output of both signals can be read directly on panel meter. Output amplitude continuously adjustable from zero up to 5.5v maximum for both in-phase and quadrature outputs. Price: $825.00

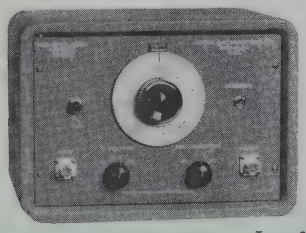
DIFFERENTIAL VOLT-NULL METER



Type 21

Measure voltage difference between two points above ground. High sensitivity, 10 uv dc per division. Accuracy ±3% on all dc ranges from 1 mv to 300v full scale. Perfect stability, essentially no drift. Input impedance 20 megohms balanced between terminals for dc measurement, 10 megohms to ground for all ranges. For ac measurement input impedance is 250 shunted with 10 uuf. Price: $335.00.

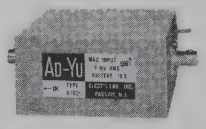
SUB-AUDIO TUNED AMPLIFIER



Type 301

Selects fundamental components of non-sinusoidal waveform. Frequency response 35 db down for second harmonic, 45 db down for third harmonic, 50 db down for higher harmonics. Center frequency 0.3 cps to 3000 cps, continuously adjustable. Gain 36 db at center frequency. Input impedance 6 megohms shunted with 25 uuf. Output impedance 200 ohms. Price: $495.00.

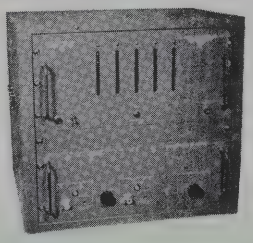
WIDE-BAND PRE-AMPLIFIERS



Type A102E, A102J, A102N

Distortion less than 1%. Noise level less than 5 uv. Completely transistorized. No hum, non-microphonic. Size 2⅞"x1 $\frac{7}{16}$"x1½" including battery, except A102N. A102E—1 cps to 5 mc, gain 100, maximum output 4v rms. A102J—1 cps to 1 mc, gain 100, maximum output 4v rms. A102N—100 cps to 17 mc, gain 200, maximum output 2v rms. Price: $88.00.

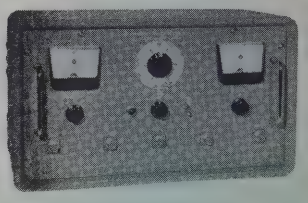
ULTRA-LOW FREQUENCY PHASE ANGLE COUNTER



Type 1002

Measures instantaneous phase angles directly in five digits. Revolutionary new gating circuit with interlocking arrangement offers dependable operation. Frequency range 0.0001 cps to 1 kc. Accuracy ±0.5°. Input voltage 0.5 to 120v. Input impedance 1 megohm shunted with 30 uuf. Price: $1388.00.

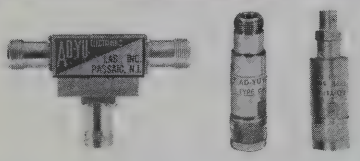
FREQUENCY CONVERTER



Type 305

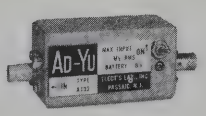
Converts RF signal from 500 kc up to 100 mc to audio frequency for measuring phase and amplitude ratio with Type 405. requires a local oscillator with frequency about 20 kc above or below the RF signal. Input impedance 50 ohms. Variable coaxial attenuator in steps of 5 db up to 25 db is provided in E1 channel. Price: $775.00.

MICROWAVE COMPONENTS



CA Series Coaxial Attenuators: 1 to 20 db attenuation in 1 db steps, Impedance 50 ohms standard, others available on request. CT Series Terminations: 50 ohms standard, VSWR less than 1.2 up to 3 kmc. Matching Divider MC-101 is used for matching one 50-ohm source to two 50-ohm loads usable from d.c. up to 3 kmc. Impedance Converter MC-102A matches 50 to 75 ohms, MC-102B matches 50 to 95 ohms usable from d.c. up to 2 kmc. Price: $22.00 and up.

MINIATURE PRE-AMPLIFIERS



Type A102, A102B, A102K

Distortion less than 1%. Noise level less than 3 uv. Self-powered, completely transistorized. Size 2⅞"x1 $\frac{7}{16}$"x1½" including battery. A102—1 cps to 100 kc, gain 100, maximum output 4v rms. A102B—1 cps to 150 kc, gain 150, maximum output 2v rms. A102K—35 cps to 140 kc, gain 6000, maximum output 4v rms. Price: $59.00 and up.

CONT. VARIABLE BANDPASS FILTER

Type A103 Series

Selects fundamental components from a distorted signal from 40 cps to 40 kc. 40 db attenuation for harmonics. Center frequency continuously adjustable in four groups: 1.5 to 1 range, 2 to 1 range, 3 to 1 range and 6 to 1 range. input impedance over 100k. The average 3 db bandwidth points are located at 6% off center frequency, 10 db at 10% off center frequency. Price: $59.00 and up.

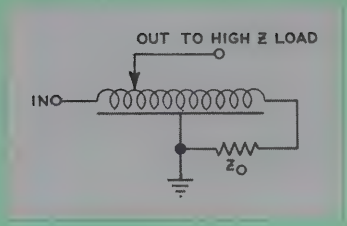
MAGNETIC AMPLIFIER RELAYS

RL-101-2-3-4

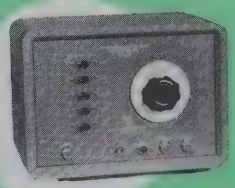
Very high sensitivity: responds to control power of 30 microwatts. Ruggedness: control winding can be continually overloaded 1000 times without damage. Contact rating up to 15 amperes. No transistors, vacuum tubes or delicate mechanisms. No adjustment required throughout the service life. Price: $85.00 and up.

CONTINUOUSLY VARIABLE DELAY LINES

STEP VARIABLE AND FIXED



VARIABLE DELAY NETWORK TYPE 2011 - 2014



FEATURES • The time delay is continuously variable with resolution time less than 8 x 10^{-11} second . . . Consists of input amplifier, one step delay line, one continuously variable delay line and two output cathode followers . . . Passing signals of any waveform . . . No time jitter.

SPECIFICATIONS

ACCURACY OF TIME DELAY: 2% of time delay at any point. Maximum error can be less than 10^{-9} second or 0.3% of time delay at any point (whichever is larger) with correction factors.

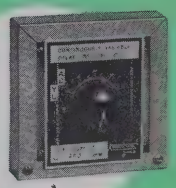
TIME DELAY: Continuously variable from 0 to 11 us for 2011, 16 us for 2012, 22 us for 2013, 32 us for 2014.
RISE TIME: Less than 4% of total delay.

BANDWIDTH: The cutoff frequency is 10 megacycles for the continuously variable delay line; 32/D for the step variable delay, where D is the total time delay.

IMPEDANCE: 20 uuf shunted with 1 megohm direct for input; about 300 ohms for output.

PRICE: $285.00 and up.

CONTINUOUSLY VARIABLE DELAY TYPE 505 - 509



FEATURES • Resolution time less than 8 x 10^{-11} second . . . Load impedance may be made equal to characteristic impedance . . . Rise time less than 10% of the time delay . . . Physical size 1" x 4-3/16" x 4-3/16", except 1" x 6-1/32" x 6-1/32" for 507 and 509 series. **PRICE:** $59.00 and up.

TYPE	Td(us)	Zo (ohms)
505	0.05	300
505a	0.1	150
505b	0.12	650
505c	0.15	750
506	0.25	200
506a1	0.22	1200

TYPE	Td(us)	Zo (ohms)
506b	0.28	300
506e	1.1	50
506f	0.75	75
506g	0.55	100
506h	0.36	150
507	0.8	650

TYPE	Td(us)	Zo (ohms)
507a	0.5	200
507b	0.5	400
507c	1.2	500
508	0.5	580
508a	0.25	1100
508b	0.66	600

TYPE	Td(us)	Zo (ohms)
509l	1	600
509a	1.25	700
509b	1.5	560
509c	1.75	460
509d	2.0	410
509e	2.5	350

TYPE	Td(us)	Zo (ohms)
509f	3.0	290
509g	3.5	250
509h	4.0	210
509i	5.0	170
509j	6.0	140
509k	7.5	100

CONTINUOUSLY VARIABLE DELAY TYPE 521 - 551 - 558

FEATURES • Continuously variable delay down to zero . . . 521 series consists of continuously variable delay line and step variable delay line connected coaxially; 551-6 series are excellent for use at high frequency, such as delaying IF signals from 1 mc to 60 mc . . . Type 557-8 series are suitable for precision trimming of time delay, extremely small size, 0.015 us to 0.3 us total delay . . . Rise time less than 4% for 521 series, 10% to 15% for 551-8 series . . . Temperature coefficient 0.005% per degree C . . . **PRICE:** Type 521 Series—$188.00; Type 551-8 Series—$68.00 and up.

TYPE	Td(us)	Zo (ohms)
521a	6	500
521b	9	750
521c	15	1200
521d	21	1200
521e	30	500
551a1	0.4	50
551b1	1.0	50

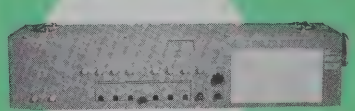
TYPE	Td(us)	Zo (ohms)
551c	20	50
552a1	0.3	75
552b1	0.6	75
552c1	1.5	75
552d1	4.5	75
552e	8.8	88
553a1	2.2	120

TYPE	Td(us)	Zo (ohms)
553b1	3.6	120
553c1	5.5	140
553d	10	178
553d1	0.6	500
553e	15	200
553e1	1.0	500
553f	20	200

TYPE	Td(us)	Zo (ohms)
553g	10	600
554a	0.1	175
554b	0.045	200
554d	0.029	190
554e	0.059	100
554f	0.05	80
555a	0.05	150

TYPE	Td(us)	Zo (ohms)
555b	0.06	135
555c1	0.02	205
555d1	0.01	185
556a	0.2	400
556b	0.3	475
556c	0.4	585
556d1	0.5	725

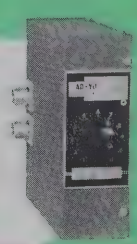
WIDE-BAND TIME DELAY STANDARD TYPE 20A1-A6 - 20B1-B2



FEATURES • Rise time less than 1 micromicrosecond . . . Bandwidth over 2000 megacycles for 20B Series; 200 megacycles for 20A Series with delay up to 1.1 us and 5 megacycles above 1.1 us . . . Readability better than 0.005 uus for 20B2, 0.01 uus for 20B1 on supervernier scale . . . Accuracy better than 1% . . . Input voltage over 500 volts . . . Type 20B1-B2 motordriven, 115V (220V available). **PRICE:** $285.00 and up.

TYPE	20B1	20B2	20A1	20A2	20A3	20A4	20A5	20A6
Zo	50 ohms	50 ohms	93 ohms	93 ohms	75 ohms	75 ohms	50 ohms	50 ohms
Resolution Time	infinitesimal	infinitesimal	10 mus	10 mus	10 mus	10 mus	10 mus	10 mus
Total Delay Time	47.8 mus	47.65 mus	11.1 us	1.1 us	1.1 us	11.1 us	1.1 us	11.1 us

STEP VARIABLE DELAY TYPE 602 - 603



FEATURES • Equal input and output impedance . . . Rise time less than 4% of total time delay . . . Temperature coefficient 0.005% per degree C . . . Operating temperature −55°C to +125°C . . . Cutoff frequency equals 35/D, where D is total time delay . . . 11 different steps with delay per step equal to total delay divided by 11. **PRICE:** $144.00.

TYPE	601	602	602a	602a1	602b	602c1	602c2	602d	602e	602e1	602e2	602f	602g	602g0	602g1	602g2	602g3
DELAY (us)	2.2	2.75	2.75	5.5	1.1	2.2	3.3	8.25	2.75	1.1	2.2	5.5	3.3	1.1	2.2	5.5	11
Zo (ohms)	200	200	75	75	75	75	50	75	50	50	50	50	300	300	300	300	300
DELAY/STEP	0.2	0.25	0.25	0.5	0.1	0.2	0.3	0.75	0.25	0.1	0.2	0.5	0.3	0.1	0.2	0.5	1
TYPE	602g4	602h	602h1	602h2	602i	602j	602k	602k1	602k2	603	603a2	603a3	603a4	603a5	603a6	603b	603b1
DELAY (us)	16.5	5.5	11	27.5	1.1	5.5	11	2.2	3.3	27.5	5.5	11	22	1.1	2.2	5.5	11
Zo (ohms)	300	500	500	500	93	93	93	93	93	600	600	600	600	100	100	1000	1000
DELAY/STEP	1.5	0.5	1	2.5	0.1	0.5	1	0.3	2.5	0.2	0.5	1	2	0.1	0.2	0.5	1

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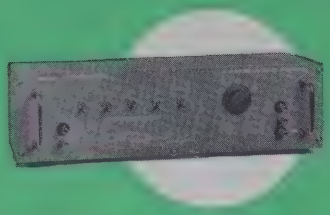
CONTINUOUSLY VARIABLE DELAY TYPE 611



FEATURES • Temperature coefficient less than 0.005% per degree C. No. time jitter . . . Fast rise time . . . Accurate dial setting.

Specifications

RISE TIME: Less than 3% of the total time delay at any point.

PHYSICAL SIZE: Panel Space—3½" x 19" with standard rack mount slots. Cabinet—7½" deep, approximately.

ATTENUATION: Less than 5 db for all types.

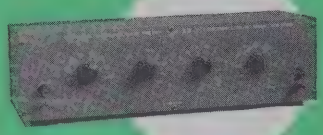
TIME DELAY VARIATION: Continuously variable with incremental time delay less than 8×10^{-11} second for Type 611a's; variable in step of one part per 320 for Type 611b's.

PRICE: $228.00 and up.

TYPE	TOTAL DELAY	FINE CONTROL RESOLUTION TIME	OUTPUT Zo
611a1	8 us	8×10^{-11} sec.	600
611a21	16 us	8×10^{-11} sec.	1200
611a3	32 us	8×10^{-11} sec.	750
611b1	16 us	0.05 us	150
611b21	16 us	0.05 us	500

TYPE	TOTAL DELAY	FINE CONTROL RESOLUTION TIME	OUTPUT Zo
611b3	8 us	0.025 us	150
611b4	12 us	0.05 us	800
611b5	32 us	0.1 us	400
611b6	64 us	0.2 us	400
611b7	128 us	0.4 us	150

DECADE VARIABLE DELAY TYPE 801



FEATURES • Incremental time delay less than 8×10^{-11} second; total time delay over 200,000 microseconds . . . Insertion loss 3 to 6 db for all types . . . Temperature coefficient less than 0.005% per degree C. **PRICE:** $345.00 and up.

Specifications

RISE TIME: Maximum rise time is less than 3% for 801a, b, b1 and c: about 2% for all other types.

PANEL SPACE: Front panel is 7" x 19" for 801c and d, 3½" to 5¼" x 19" for all others, with standard rack mount slots.

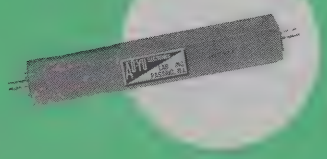
CUTOFF FREQUENCY: Type 801 Series—At maximum delay, the cutoff frequency is 30/D. Type 802 Series—At maximum delay, the cutoff frequency is 60/D, where D is the total time delay.

DISTORTION: Less than 3% for all types.

TYPE	TOTAL DELAY	FINE CONTROL RESOLUTION DELAY	INPUT Zo	ATTEN. db
801a	50 us	8×10^{-11} sec.	500	2
801b	100 us	8×10^{-11} sec.	500	3
801b1	200 us	8×10^{-11} sec.	250	3
801c	500 us	8×10^{-11} sec.	500	3
801d	1,000 us	8×10^{-11} sec.	500	4
801e	2,000 us	0.2 us	500	7

TYPE	TYPE	TOTAL DELAY	FINE CONTROL RESOLUTION TIME	INPUT Zo	ATTEN. db
801f	802f	5,000 us	0.5 us	1250	8
801g	802g	10,000 us	1 us	500	8
801g1	802g1	20,000 us	2 us	250	8
801h	802h	50,000 us	5 us	500	8
801i	802i	100,000 us	10 us	2500	10
801j	802j	200,000 us	20 us	1100	12

ULTRA-FAST RISE TIME DELAY TYPE 10T - 11T



FEATURES • Rise time can be made less than 2% of total delay . . . Phase linear to 2/3 of cutoff frequency . . . Distortion 2% . . . Temperature coefficient less than 0.005% per degree centigrade . . . Attenuation less than 6 db maximum for 10T Series; less than 3 to 12 db maximum for 11T Series.

Specifications

TOTAL TIME DELAY: 10T—0.1, 0.15, 0.2 up to 18 us; 11T—400 up to 120,000 us.

CHARACTERISTIC IMPEDANCE: 10T—50 up to 500 ohms; 11T—500 up to 10,000 ohms.

INPUT VOLTAGE: 10T—500 volts maximum; 11T—30 volts maximum.

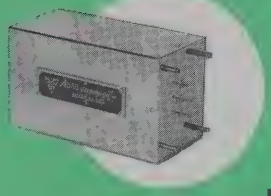
NUMBER OF SECTIONS: 10T—20 to 120 sections; 11T—40 to 100 sections.

NUMBER OF TAPS: 10T—2 taps; 11T—2 taps, standard; additional taps on request.

PHYSICAL SIZE: 10T—1" x 1" x 8⅛" or larger; 11T—7¾" x 7¾", length 5-11/16" or 14⅛"; or rack mount 5¼" x 19".

PRICE: 10T—$38.00 and up; 11T—$215.00 and up.

TAPPED DELAY LINES TYPE 5T - 9T



Specifications

NUMBER OF SECTIONS: 5T—100 sections; 9T—40 to 240 sections.

RISE TIME IN PERCENTAGE OF TOTAL DELAY: 5T—2-3%; 9T—7% for 40 sections to 2% for 120 sections and above.

INPUT VOLTAGE: 300 volts maximum for most types.

TEMPERATURE COEFFICIENT: Less than 0.005% per degree centigrade.

ATTENTUATION: Approximately 1-6 db maximum for all types.

TOTAL TIME DELAY: 5T—1, 1.5, 2 up to 600 us; 9T—12, 15, 16, 18 up to 240 us.

CHARACTERISTIC IMPEDANCE: 5T—50, 75, 100 up to 2000 ohms; 9T—300, 500, 600 up to 2500 ohms.

NUMBER OF TAPS: 2 taps; additional taps on request. Taps with continuously adjustable delay can be installed.

PHYSICAL SIZE: 5T—2⅛" x 2¼" x 5" or larger, vertical mounting; 9T—⅞" x 2⅝" x 5½" or larger, horizontal mounting; vertical mounting with approximately same volume available. Printed circuit board mounting available in small size.

PRICE: 5T—$112.00 and up; 9T—$72.00 and up.

TAPPED DELAY LINES TYPE 6T - 7T - 8T

Specifications

NUMBER OF SECTIONS: 6T—10 sections; 7T—30 sections; 8T—20 sections of M-derived network.

RISE TIME IN PERCENTAGE OF TOTAL DELAY: 6T—15%; 7T—8%; 8T—10%.

INPUT VOLTAGES: 500 volts maximum for most types.

TEMPERATURE COEFFICIENT: Less than 0.005% per degree centigrade.

TOTAL TIME DELAY IN US: 0.1, 0.15, 0.2, 0.3, 0.4, 0.45, 0.5 up to 36 us.

CHARACTERISTIC IMPEDANCE IN OHMS: 50, 75, 100, 200, 300, 500, 600, 750, 1000, 2000, 2500 and 3000.

NUMBER OF TAPS: Horizontal mounting. 6T—11 taps; 7T—4 taps; 8T—6 taps. Vertical mounting, 2 taps; additional taps on request. Taps with continuously adjustable delay can be installed.

PHYSICAL SIZE: Horizontal mounting, 6T—6-1/16" x 15/16" x ⅞"; 7T—5⅝" x 2-11/16" x 15/16"; 8T—5⅝" x 15/16" x 1-13/16"; vertical mounting with approximately same volume available. Printed circuit board mounting available in small size.

PRICE: 6T—$22.00 each; 7T—$42.00 each; 8T—$32.00 each.

MINIATURE DELAY LINES TYPE 3T - 6C - 7C

FEATURES • Physical Size: 3T series—1" x 1" x 2¼" or larger; 6C series—¼", ⅜" or 5/16" dia., 1" to 6" long; 7C series—⅝" x ⅝" square, 2¾" to 4½" long . . . Rise time approximately 6% to 12% of total delay for 3T series, depending on number of sections; 14% for 6C series; 12% for 7C series.

Specifications

CHARACTERISTIC IMPEDANCE IN OHMS: 50, 75, 100, 150, 200, 300, 500, 600, 750, 1000 and 1500.

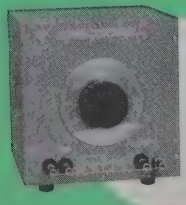
TIME DELAY IN US: 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.6, 0.75 up to 60 us.

FREQUENCY RESPONSE: 6C series—over 10 megacyles; 7C series—cutoff frequency equals 3/D, 3T1 series—4/D, 3T2 series 6/D, where D is the total time delay of the unit.

WEIGHT: Less than 6 ounces.

PRICE: 3T—$22.00 and up; 6C—$13.50 each; 7C—$22.00 each. Quantity discounts.

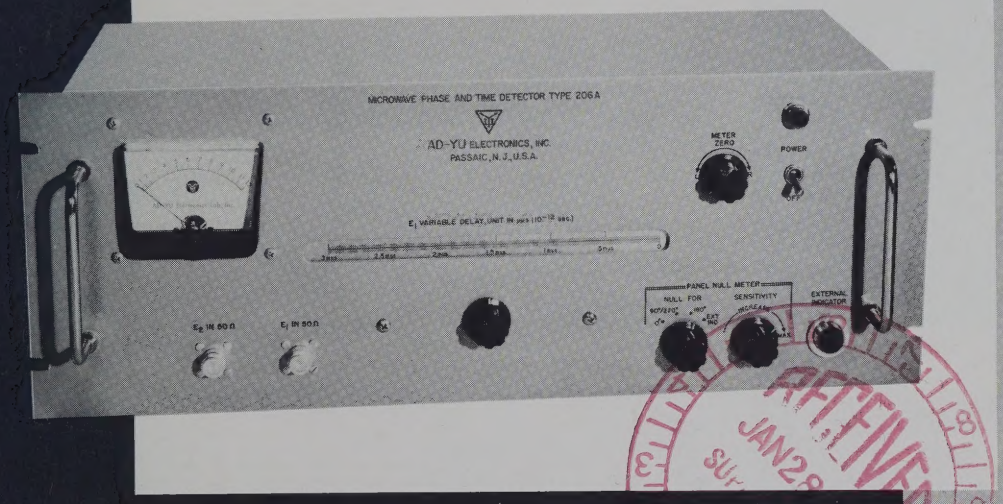
STEP VARIABLE DELAY LINES TYPE 605 - 606



FEATURES • Time delay accuracy ±1% at any point . . . Temperature coefficient 0.005% per degree C . . . Can be used for matched low output impedance . . . Time delay per step 1/60 of the total time delay for Type 605, 1/120 for Type 606 and 607 . . . Rise time less than 5% for Type 605, 3% to 2% for Type 606, 2% or less for Type 607 . . . **PRICE:** $130.00 and up.

TYPE	605a	605a1	605b	605c	605c1	605c2	605d	605e	605f	605g	605h	605i	605i1	605i2	605i3	605j	605k	605l	605m
DELAY	.6 us	1.2 us	1.5 us	3 us	3 us	4.5 us	6 us	12 us	9 us	30 us	48 us	60 us	75 us	150 us	300 us	600 us	1200 us	2400 us	6000 u
Zo	75	75	95	190	50	75	300	760	150	1000	620	500	1000	500	500	1000	500	1000	500
TYPE	606a	606a1	606b	606c	606c1	606c2	606d	606e	606f	606g	606h	606i	606i1	606i2	606i3	606j	606k	606l	606m
													607i1	607i2	607i3	607j	607k	607l	607m
DELAY	1.2 us	2.4 us	3 us	6 us	6 us	9 us	12 s	24 us	18 us	60 us	96 us	120 us	150 us	300 us	600 us	1200 us	2400 us	4800 us	12000u
Zo	75	75	95	190	50	75	300	760	150	1000	620	500	1000	500	500	1000	500	1000	500

Microwave Phase and Time Detector Type 206



FEATURES:

- Phase and time measurement from 1100 mc to over 18 kmc with accuracy better than 0.1° or 1% over the entire range from 0° to 360°.
- Suitable for pulsed sine wave with no limitation on duty cycle.
- Accuracy not affected by amplitude fluctuation of both input signals with the 90°/270° method.
- Servo output available for automatic phase control.
- Useful for signal levels below 1 millivolt with external receiver as detector.
- Infinitesimal resolution, readability better than 0.005 uus 5×10^{-15} second) with super vernier scale.
- Capable of plotting phase vs. frequency curve on an oscilloscope or recorder.
- Based on comparison principle, no errors due to meter movement and tolerance of circuit elements.
- Both input signals enter separate channels and are accurately terminated, no error due to interaction between channels.

RECEIVED JAN 28

AD-YU ELECTRONICS, Inc.

249-259 TERHUNE AVENUE, PASSAIC, N. J., U. S. A.

The operating principle of the instrument is described in an article entitled, "Phase Measurement at High Frequency" by Dr. Y. P. Yu, President and Chief Engineer of this company, page 677-684 of the National Electronics Conference 1960. The instrument is based on the comparison principle, as a result, error due to meter movement and tolerance of circuit elements are completely eliminated. Each RF signal enters a separate channel and is completely shielded. Therefore, errors due to interaction between two input signals and high VSWR caused by mismatch between signal sources (as in the case of feeding two signals into both ends of a single slotted line) are completely eliminated. The block diagram of the instrument (patent pending) is shown in Fig. 1. Input signal E_1 is shifted 90° by means of the continuously variable delay line before the sum/difference network. The output voltages from the sum/difference network enters two separate isolators, then to the rectifiers. Fig. 2 shows a vector diagram for the relations between the output voltages and both input signals. If the phase angle between E_1 and E_2 is made exactly 90° with the continuously variable delay line, the absolute amplitude of $|E_1+E_2|$ will always equal the absolute amplitude of $|E_1-E_2|$, because they form two diagonals of a rectangle. Therefore, the output of the phase detector is zero regardless of the variation of signal amplitudes of both E_1 and E_2 as long as their phase difference is 90°. In addition, the phase detector produces no output if the frequency of the unknown signal E_2 is not equal to the frequency of the reference signal E_1, because their average product is zero. Therefore, the accuracy of the instrument is not affected by noise and harmonics. In Fig. 3, the upper shaded area represents the electric charge introduced by the rectifier diode for the E_1+E_2 channel. Likewise, the lower shaded area represents the electric charge introduced by the rectifier diode for the E_1-E_2 channel. These two areas are equal, and their difference, which is the output of the detector, is always zero. Therefore, the even harmonics of E_2 will also produce no error to the phase detector of this kind. However, the odd harmonics of E_2 will introduce a small percentage of error as given in the specifications. The calibration of the continuously variable delay line can be traceable to the frequency standard of the National Bureau of Standards.

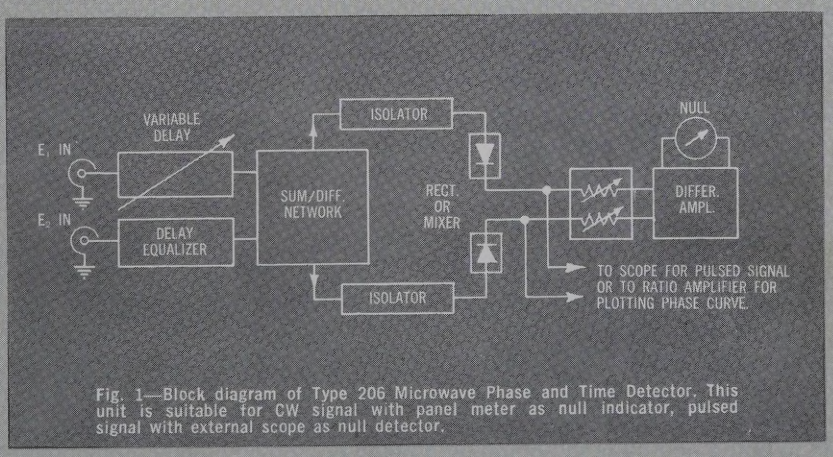


Fig. 1—Block diagram of Type 206 Microwave Phase and Time Detector. This unit is suitable for CW signal with panel meter as null indicator, pulsed signal with external scope as null detector.

The principle of operation is based on the fact that dial reading for minimum $|E_1-E_2|$ should remain unaltered when a time delay equal to one period of the applied signal frequency is added to either E_1 or E_2 channel. Therefore, the delay line scale can be calibrated with the frequency of the signal generator.

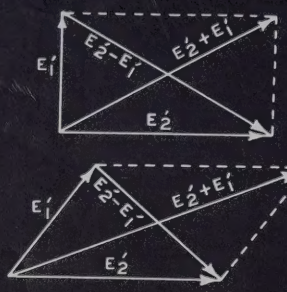


Fig. 2—(left) Vector diagram of the sum/difference network $|E_1+E_2|$ equals $|E_1-E_2|$ when E_1 is 90° in respect to E_2.

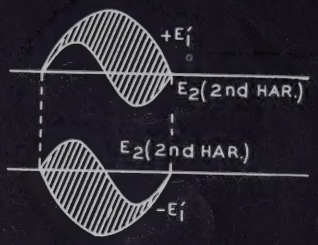


Fig. 3—(right) No response to even harmonics since the shaded areas for the sum and difference network are exactly equal.

SPECIFICATIONS

ACCURACY:

Less than ±0.1° or ±1% error over the entire frequency range.

RESOLUTION AND READABILITY:

The resolution is infinitesimal for both Type 206A and Type 206B. Readability is 10 picoseconds per division on the main scale, 0.1 picosecond per division on the vernier scale, 0.01 picosecond per division on the super vernier scale, 0.005 picosecond can be read.

MINIMUM SIGNAL:

Approximately 5 millivolts with a receiver having 1 microvolt sensitivity as external null indicator. Approximately 0.2 volt rms with the panel meter as null indicator.

RATIO OF INPUT SIGNALS:

Varied from 1:1 to as high as 50:1 for Type 206A; 10:1 for Type 206B without affecting the accuracy.

MAXIMUM SIGNAL:

20 volts rms can be accomplished by using termination with higher wattage.

FREQUENCY RESPONSE:

Type 206A series has a bandwidth of 1100 mc to 6000 mc with 4 plug-in units; Type 206A1, 1100 mc to 1700 mc; Type 206A2, 1600 mc to 2400 mc; Type 206A3, 2400 mc to 3600 mc; Type 206A4, 3600 mc to 6000 mc. Type 206B series has bandwidth approximately ±25% of center frequency; Type 206B1 for 3.95 kmc to 5.85 kmc, Type 206B2 for 5.85 kmc to 8.2 kmc, Type 206B3 for 8.2 kmc to 12.4 kmc, Type 206B4 for 12.4 kmc to 18 kmc.

DELAY AND PHASE RANGE:

The total delay range for Type 206A series is 800 uus (8×10^{-12} second) which corresponds to a phase range of 360° at 1250 mc. The phase range for each Type of 206B series is continuously adjustable from zero to 180° minimum at its operating frequency.

INPUT VSWR:

1.03 at low frequency and increases slowly to 1.1 maximum at high frequencies for both Type 206A and Type 206B.

ERROR DUE TO HARMONICS AND NOISE:

Noise and even harmonics will introduce no error to Type 206A and Type 206B, except odd harmonics. approximately 1% for 3% content of third harmonic; 0.5% for 3% of fifth harmonic.

PULSED SIGNAL:

The instrument will accept pulsed signal with no limitation on duty cycle except the brightness of the oscilloscope used as detector will be decreased as the duty cycle decreases. The instrument also has no limitation on pulse width, except the time constant of the rectifier may have to be reduced for pulse width less than 0.5 microsecond.

PRICE:

Type 206A, $2386.00 each with one plug-in unit; Type 206B1, $2586.00; slightly higher for other types of 206B series. FOB Passaic, N. J.

Type 206 Microwave Phase and Time Detector is very suitable for precision comparison of phase angle or time delay between an unknown network, filter, or r.f. amplifier with respect to a standard, see Fig. 4. The time delay of both channels including the connecting cables are first balanced by means of adjusting the continuously variable delay line of Type 206 until the panel meter reaches null. Then insert the unknown in E_1 channel and the standard in E_2 channel. Now again adjust the continuously variable delay line until the panel meter reaches null. The difference of the readings on the continuously variable delay dials becomes the error of time delay or phase difference between the unknown and the standard.

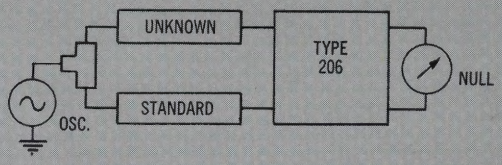


Fig. 4—Use of Type 206 for comparison of phase angle or time delay between an unknown and a standard.

Pulse modulated signal can be used for testing the phase angle or time delay of an unknown network or traveling wave tube, klystrons, etc., with an oscilloscope as external null indicator, see Fig. 5. First, balance the delay without the unknown network, then insert the unknown in one channel and adjust the variable delay line again for zero pulse deflection on the oscilloscope. The difference of dial readings is the time delay of the unknown. Pulse width can be as low as 1 us. The limit on duty cycle is governed only by the brightness of the oscilloscope, Type 206 has no limitation on duty cycle.

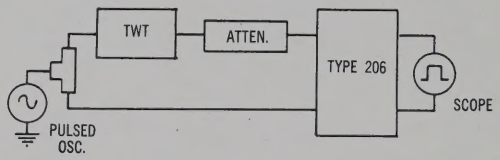


Fig. 5—Use of Type 206 for phase measurement of traveling wave tubes, with pulse modulated signal.

Phase angle over 360°, or more than one wave length, can be measured by using two frequencies. In Fig. 6, first measure the delay of the unknown microwave delay line at frequency fa. Let the delay reading be $ta=t_1a-t_2a$, where t_1a is the delay dial reading without the unknown and ta_2 is the delay reading with the unknown. Then an expression for the unknown delay can be written as: $D=ta+nTa$ where Ta is the period at frequency fa, such as $Ta=1/fa$, and n is the number of wave lengths. Now increase the frequency slightly to fb and the delay reading on the dial of Type 206 is tb, such as $D=tb+nTb$ where $Tb=1/fb$. The unknown delay can be found by solving these two equations for D and n.

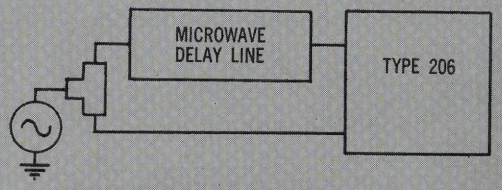


Fig. 6—Measure phase shift over 360° of microwave delay line with two-frequency method.

Phase or time measurement with signal levels below 10 millivolts can be accomplished with Type 206 Microwave Phase and Time Detector and an external receiver as null indicator. In Fig. 7, the attenuator is adjusted to yield approximately equal signals to Type 206. If an external receiver with sensitivity of 1 to 2 microvolts is used for nulling, good sensitivity can be obtained even when E_1 and E_2 are down to 5 millivolts.

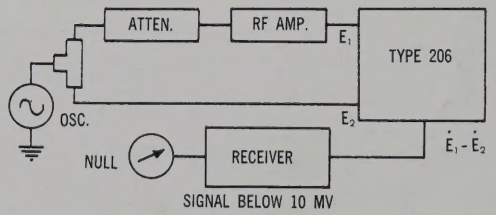


Fig. 7—Use of Type 206 for phase or time measurement below 10 millivolts.

Phase vs. frequency curve of an unknown network can be plotted automatically on an oscilloscope or recorder with Type 206 Microwave Phase and Time Detector, see Fig. 8. When the amplitudes of E_1 IN and E_2 IN are adjusted to be essentially constant the ratio of the rectified output $|E_1-E_2|$ and $|E_1+E_2|$ will be proportional to the tangent of phase angle between E_1 and E_2. Thus, by applying $|E_1+E_2|$ and $|E_1-E_2|$ to a ratio amplifier, an oscilloscope can be used to plot the output of the ratio amplifier as the phase curve between E_1 and E_2.

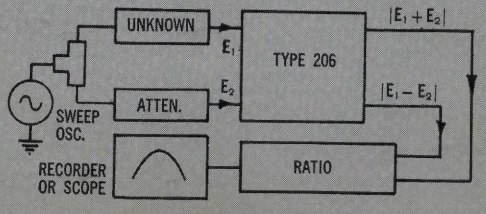


Fig. 8—Automatic plotting of phas vs. frequency curve with Type 20

Audio and Video Phase Meters—Direct reading in degrees, no amplitude adjustment, no frequency adjustment, 1 cps to 10 mc. Analog output for recorders or programmable systems.

Microwave Phase Meters—15 mc to 18000 mc, accuracy ±0.05° or ±1%. Suitable for CW or pulsed signals.

Transistorized Pre-Amplifiers—Bandwidth 1 cps to 17 mc, 4 volts rms output.

Wide-Band Time Delay Standards—Useful up to 1700 mc. Continuously adjustable. Calibration traceable to NBS standards.

Decade Delay Lines—Adjustable in four decades. Rise time 2%, up to 100 milliseconds total delay.

World famous for phase measuring instruments from sub-audio to microwave frequencies. Delay lines, continuously variable, step variable, fixed and tapped, and other electronic instruments.

DR. Y. PAUL YU
President and Founder

249 Terhune Avenue Passaic, New Jersey